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ST. ANNE'S ARTS AND SCIENCE COLLEGE

GNT Road, Madavaram, Chennai – 600 110

(Affiliated to the University of Madras)



International Journal of Current Research and Academic Review

INTERNATIONAL CONFERENCE

CONVERGENCE OF COMPUTING, MATHEMATICS AND MICROBIOLOGY:
CHALLENGES AND OPPORTUNITIES

SAASC-CCMMCO-25

20th SEPTEMBER 2025

Volume 1



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Dr.I.Annammal Arputhamary

Principal

Conference Organizing Secretary

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Dean of College Development

ORGANISED BY

**IQAC & Department of Computer Science ,
Computer Applications, Mathematics and Microbiology**

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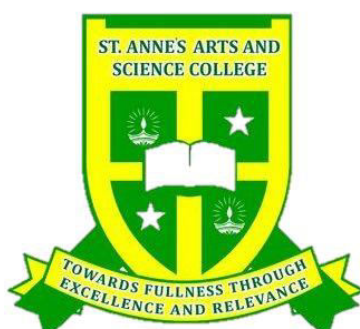
INTERNATIONAL CONFERENCE ON

CONVERGENCE OF COMPUTING, MATHEMATICS AND MICROBIOLOGY: CHALLENGES AND OPPORTUNITIES

SAASC–CCMMCO-25

on

20th September, 2025



International Journal of Current Research and Academic Review

ORGANIZED BY

**IQAC & Department of Computer Science ,
Computer Applications, Mathematics & Microbiology.**

ST. ANNE'S ARTS AND SCIENCE COLLEGE

GNT Road, Madavaram, Chennai – 600 110

ISO 9001:2015 CERTIFIED INSTITUTION

(Affiliated to the University of Madras)

ABOUT THE COLLEGE

St. Anne's Arts and Science College, Chennai has been an institution that has focused on achievements in the field of higher education for young women. The future belongs to those who believe in the beauty of their dreams. Our foundress **Thatipathri Gnanamma** is our role model, whose vision and dreams have served as an inspiration for hard work and determination.

Our journey of stepping into higher education started with the courage and will power of our Chairperson, **Rev. Mother Dr. Leema Rosario**, whose path to success towards higher education was through determined action. The College strive to achieve academic excellence, by providing quality education through excellent teaching-learning activities, research pursuits and through a continuous assessment of academic activities. This is to empower young women to evolve as self-reliant citizens of the global village who would cater to human welfare and sustainability.

Vision: To provide humanizing and liberalizing education so as to form responsible citizens who in solidarity with others will create a just Society.

Mission:

- To empower youth with knowledge, skills and competence
- To provide the students with opportunities to understand the present society and critically analyze its structures
- To form their character and personality.
- To mold them into socially responsible youth.
- To enable them to create a more humane and harmonious society.
- To produce world class leaders with a difference.
- To create integrated and visionary leaders.

ABOUT THE DEPARTMENTS

DEPARTMENT OF COMPUTER SCIENCE

The Department of Computer Science was established in the year 2014-2015. This programme trains its students to showcase their skills as Software Developers, System Integrators and System Analysts among other job profiles.

DEPARTMENT OF COMPUTER APPLICATIONS

The Department of Computer Applications was introduced in 2014-2015. The course has been designed to provide a strong foundation in the area of computer applications and equip learners with the required skills needed in the industry and academia.

DEPARTMENT OF MATHEMATICS

The Department of Mathematics had its inception in the year 2014. The department prepares young minds to become efficient mathematicians and has been at the forefront in producing commendable results in the university examinations. The faculty of the department of mathematics focus on enabling students to become lifelong learners and grow in their chosen professions.

DEPARTMENT OF MICROBIOLOGY

The Department of Microbiology was started in 2022 enhanced with well-equipped laboratory. All the faculties are well experienced in research and academics. The course is designed to provide job opportunities and research in various fields such as Pharmacy, Medicine, Clinical research, Agriculture, Dairy industry, Water industry, Nanotechnology & Chemical technology.

ORGANIZING COMMITTEE

CHIEF PATRON

**Rev. Mother Dr. Leema Rosario,
Chairperson**

CONVENOR

**Dr. I. Annammal Arputhamary,
Principal**

CONFERENCE ORGANIZING SECRETARY

**Smt. M. R. Benedict Kumari,
Dean of College Development**

MESSAGE FROM THE CHAIRPERSON



It is with great pride and joy that I welcome you to this International Conference. The theme Convergence of Computing, Mathematics and Microbiology: Challenges and Opportunities embodies our belief that the greatest breakthroughs emerge when disciplines interact, ideas collide, and visions are shared.

This conference symbolizes a meeting point of innovation and imagination. By weaving together, the analytical power of mathematics, the transformative impact of computing, and the life-sustaining insights of microbiology, we create a fertile ground for pioneering research that addresses some of the most pressing challenges of our time.

The organization of this conference reflects the combined efforts of our dedicated faculty and staff, whose vision has made it possible to convene such a meaningful platform. It is my hope that the deliberations, presentations, and interactions held over the course of this conference will serve as a valuable contribution to the advancement of knowledge across these vital fields.

I pray that this gathering inspires new partnerships, fresh perspectives, and bold research that will continue to echo long after the sessions conclude. May every participant find both knowledge and inspiration in this intellectually stimulating conference.

Rev. Mother Dr. Leema Rosario
Chairperson





MESSAGE FROM THE PRINCIPAL



It gives me immense pleasure to welcome all participants to the International Conference on Convergence of Computing, Mathematics and Microbiology: Challenges and Opportunities. Inspired by the vision of our Chairperson, Rev. Mother Dr. Leema Rosario, this event reflects our shared commitment to advancing knowledge through interdisciplinary collaboration.

As a mathematician, I have always believed that mathematics is the language of logic and precision, capable of providing clarity in complexity. When mathematics joins hands with the computational power of technology and the life-sustaining insights of microbiology, the result is a symphony of ideas that can redefine the boundaries of research and application. This convergence demonstrates how structure, innovation, and life sciences can together pave new avenues for discovery.

I extend my sincere appreciation to the organizing committee for their tireless efforts in bringing together scholars, researchers, and students from across disciplines. May this conference spark insightful discussions, foster lasting collaborations, and inspire the next generation of researchers to think beyond boundaries and contribute meaningfully to society.

Dr. I. Annammal Arputhamary
Principal





MESSAGE FROM THE DEAN



It is my pleasure to welcome you to the International Conference on Convergence of Computing, Mathematics, and Microbiology: Challenges and Opportunities. Under the inspiring leadership of our Chairperson, Rev. Mother Dr. Leema Rosario, this conference brings together researchers, scholars, and practitioners to celebrate the pursuit of knowledge, innovation, and collaboration.

The theme of this conference highlights how significant progress is achieved when diverse fields converge. Mathematics provides logical reasoning, computing contributes innovative tools and methodologies, and microbiology offers critical insights into life and natural systems. Together, these disciplines help address complex scientific questions and real-world challenges.

I extend my heartfelt appreciation to the organizing departments and faculty members for their unwavering dedication in bringing this event to fruition. I wish all participants a rewarding and productive conference..

Smt. Benedict Kumari
Dean of College Development



ACKNOWLEDGEMENT

The successful organization of the International Conference on Convergence of Computing, Mathematics and Microbiology: Challenges and Opportunities is the result of collective vision, guidance, and dedication. We are deeply grateful to our Chairperson, **Rev. Mother Dr. Leema Rosario**, whose inspiring leadership and blessings have been the foundation of this endeavour. We also thank her for graciously delivering the Opening Address, which set the tone for the conference and continues to inspire us to strive for excellence.

We extend our sincere appreciation to our Principal, Dr. I. Annammal Arputhamary, and our Dean of College Development, Smt. M. R. Benedict Kumari, for their steadfast support and encouragement, which have been vital in shaping this event into a successful platform for scholarly exchange. We also place on record our gratitude to our College Advisor, Dr.S.Murugesan for his valuable guidance and support provided throughout the planning and organization of this conference. A special note of gratitude is extended to our distinguished keynote speaker, Dr. Gokul Shankar Sabesan, Professor of Microbiology and Deputy Dean, Faculty of Medicine, Manipal University, Malaysia. His keynote address was both inspiring and intellectually enriching, sparking new ideas and elevating the discussions of this conference to greater heights.

We also acknowledge the tireless efforts of the organizing committee and faculty members from the Departments of Computer Science, Computer Applications, Mathematics, and Microbiology. Their commitment and teamwork have ensured the smooth execution of this conference.

Finally, we thank all participants—academicians, researchers, scholars, and students—for their active engagement and contributions. It is our hope that the knowledge shared and the connections formed here will inspire continued collaboration and innovation across disciplines.

Department of Computer Science
Department of Computer Applications
Department of Mathematics
Department of Microbiology

ST. ANNE'S ARTS AND SCIENCE COLLEGE

G.N.T ROAD, PONNIAMMANMEDU MADAVARAM, Chennai - 600110

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INTERNATIONAL CONFERENCE ON CONVERGENCE OF COMPUTING, MATHEMATICS AND MICROBIOLOGY: CHALLENGES AND OPPORTUNITIES

(SAASC-CCMMCO-25)

20.09.2025 - SATURDAY

**Organized by
Department of Computer Science ,
Computer Applications, Mathematics and Microbiology**



**THE MANAGEMENT, STAFF AND STUDENTS OF
ST. ANNE'S ARTS AND SCIENCE COLLEGE**

**Cordially invite you to grace the Inaugural Function of our
INTERNATIONAL CONFERENCE**

on

**CONVERGENCE OF COMPUTING, MATHEMATICS AND
MICROBIOLOGY:CHALLENGES AND OPPORTUNITIES
SAASC-CCMMCO-25**

Inaugural Function : 20.09.2025@ 9.30 AM

Venue : MOTHER GNANAMMA CONFERENCE HALL

Rev. Mother Dr. Leema Rosario

Chairperson

ST. ANNE'S ARTS AND SCIENCE COLLEGE

has kindly consented to deliver the Inaugural Address

Chief Guest

Dr. GOKUL SHANKAR SABESAN

Professor, Microbiology Department

Deputy Dean - Preclinical Sciences

Faculty of Medicine, Manipal University, Malaysia

has kindly consented to deliver the Presidential Address

**Smt. M.R. Benedict Kumari
Dean College Development**

**Dr. I. Annammal Arputhamary
Principal**

PROGRAMME SCHEDULE

20.09.2025 - FORENOON SESSION

Inauguration : 9.30 am

Inaugural Address : Rev. Mother Dr. Leema Rosario
Chairperson

St. Anne's Arts and Science College

Presidential Address : Dr. Gokul Shankar Sabesan

Professor, Microbiology Department

Deputy Dean - Preclinical Sciences

Faculty of Medicine, Manipal University,

Malaysia

Tea break : 10.30 am

PAPER PRESENTATION BY PARTICIPANTS

In Person & Online

Resource Persons

VENUE 1

1. Dr. A. JOHNY

Assistant Professor, Department of Mathematics

Karpaga Vinayaga College of Engineering and Technology

Padalam, Chengalpattu.

VENUE 2

2. Dr. S. VALLI

Profressor and Head, PG and Research Department of Microbiology

Mohamed Sathak College of Arts and Science, Chennai.

VENUE 3

3. Dr. S. UMA SHANKARI

Associate Professor and Head, Department of Computer Application

SRM Institute of Science and Technology, Ramapuram, Chennai.

20.09.2025 - AFTERNOON SESSION

VALEDICTORY FUNCTION @ 2.30 pm

Chief Guest

Mr. Jayaprakash Venugopal

Associate Director

AI & Innovation Lead - India

Dedalus

has kindly consented to deliver the Valedictory Address

**Release of the Conference
Proceedings**

:

Dr. I. Arlamma
Academic Advisor

Release of the Conference CD

:

Dr. S. Murugesan
College Advisor

Opening of Link

:

Smt. M.R. Benedict Kumari
Dean College Development

Certificate Distribution

:

Smt. Y. Archana
Public Relations Officer,
Chair, Accessibility Vertical,
Young Indians Chennai

Expression of Appreciation

:

Dr. I. Annammal Arputhamary
Principal

**INTERNATIONAL CONFERENCE
ON
CONVERGENCE OF COMPUTING,
MATHEMATICS AND MICROBIOLOGY:
CHALLENGES AND OPPORTUNITIES
SAASC–CCMMCO-25**

**IJCRAR 2025
20th, September, 2025**

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Invited Talk

IJCRAR/IT/01

Opportunities and Challenges in Sciences

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Introduction

Science has always been the driving force behind human progress, shaping societies, economies, and even geopolitics. In the 21st century, the pace of scientific advancement is unparalleled, yet the challenges confronting the global scientific community are equally profound. Understanding these dynamics is essential, especially for students and young researchers who will define the future of science.

Global Challenges in Science

Climate Change and Environmental Sustainability

The Intergovernmental Panel on Climate Change (IPCC, 2023) highlights that global surface temperature has already risen by 1.1°C compared to pre-industrial levels, causing extreme weather events. Science is under immense pressure to innovate solutions in renewable energy, carbon capture, and sustainable agriculture. For example, rising sea levels threaten 600 million people living in low-lying coastal regions, demanding urgent scientific interventions.

Global Health and Emerging Diseases

The COVID-19 pandemic underscored both the strength and vulnerability of modern science. Within a year, mRNA vaccines (Pfizer, Moderna) demonstrated the power of biotechnology. Yet, unequal distribution was glaring: by early 2022, only 16% of people in low-income countries had received at least one vaccine dose. Science must address not just discovery but equitable access.



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Ethical Dilemmas in Emerging Technologies

Breakthroughs like CRISPR-Cas9 gene editing and Artificial Intelligence (AI) raise ethical concerns. For example, the case of a Chinese scientist in 2018 who claimed to have created the first gene-edited babies triggered global debate on the boundaries of scientific responsibility. Similarly, AI systems today influence healthcare, finance, and law, but raise questions of privacy, bias, and accountability.

Research Funding and Inequalities

Scientific progress is uneven. According to UNESCO (2021), 10 countries account for more than 80% of global R&D spending, leaving vast regions dependent on imported technologies. This gap widens disparities in innovation capacity and economic competitiveness.

Public Trust and Misinformation

Another critical challenge is the erosion of public trust in science, fueled by misinformation on social media. During the COVID-19 pandemic, the WHO described the phenomenon as an “infodemic,” where fake news often spread faster than scientific facts. Restoring confidence in science requires effective communication and transparency.

Illustration: The global climate crisis exemplifies how science can be both the source of solutions and the arena of political contest. While renewable energy is expanding—solar and wind power accounted for 80% of new electricity capacity worldwide in 2022—fossil fuels still dominate, showing the gap between scientific capability and implementation.

In summary, while science today faces complex global challenges, these very obstacles create opportunities for innovation and collaboration that will shape the future of humanity.

Global Opportunities and Indian Challenges

While the challenges are daunting, the opportunities in science have never been greater. We live in an era where interdisciplinary research, international collaborations, and digital tools are opening new frontiers.



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Global Opportunities in Science

Artificial Intelligence and Digital Transformation

AI is revolutionizing multiple sectors. In healthcare, AI algorithms can detect breast cancer in mammograms with accuracy levels comparable to radiologists. In agriculture, AI-based precision farming helps optimize crop yields while reducing water use. According to PwC (2021), AI could contribute \$15.7 trillion to the global economy by 2030.

Space Exploration

Humanity's curiosity about space has translated into scientific breakthroughs. NASA's James Webb Space Telescope (launched 2021) is already providing images of galaxies formed 13 billion years ago. Private companies like SpaceX are reducing the cost of space travel, while India's Chandrayaan-3 demonstrated the capacity of emerging economies to lead in space exploration.

Biotechnology and Precision Medicine

The Human Genome Project (completed 2003) laid the foundation for personalized medicine. Today, cancer immunotherapies, 3D bioprinting of organs, and CRISPR-based therapies promise revolutionary treatments. The global biotech market is projected to reach \$3.44 trillion by 2030 (Grand View Research, 2023).

Green Technologies

Renewable energy is a fast-growing opportunity. The International Energy Agency (IEA) projects that by 2030, renewables will supply almost half of the world's electricity demand. Innovations in hydrogen fuel, battery storage, and smart grids are redefining energy systems.

Challenges in India

While global opportunities abound, India faces unique hurdles in leveraging science fully:

- **Limited R&D Investment**

India spends ~0.7% of its GDP on R&D, compared to the US (2.8%) and China (2.4%). This underinvestment limits infrastructure, advanced labs, and high-end research facilities.



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- Infrastructure and Bureaucracy

Research in India often suffers delays due to outdated facilities and bureaucratic procedures in grants and approvals, slowing innovation.

- Brain Drain

Many talented students and scientists migrate abroad. For example, over 7.5 lakh Indian students studied overseas in 2022, many in STEM fields.

- Inequality in Science Education

While top institutes like IITs and IISc are globally competitive, there is a significant urban-rural divide. Lack of access to labs, internet, and resources hampers students in rural India from pursuing scientific careers.

Illustration: India produces 1.5 million engineering graduates annually, yet only a small fraction engages in cutting-edge research. Bridging this gap requires systemic reforms in funding, mentorship, and career pathways.

Opportunities in India, Way Forward, and Conclusion

Despite challenges, India holds immense promise in science and innovation. Its large youth population, expanding digital ecosystem, and strategic government initiatives are laying the groundwork for future breakthroughs.

Opportunities in India

Space Research Leadership

ISRO has achieved global recognition through cost-effective missions. The success of Chandrayaan-3 (2023), landing near the Moon's south pole, positioned India as the fourth country to achieve a soft lunar landing. Such achievements inspire confidence and open commercial opportunities in space technology.

2. Pharmaceuticals and Biotechnology

India is often called the "Pharmacy of the World." During COVID-19, it supplied vaccines to over 100 countries under the "Vaccine Maitri" initiative. The Indian biotech industry is projected to reach \$300 billion by 2030 (IBEF, 2023).

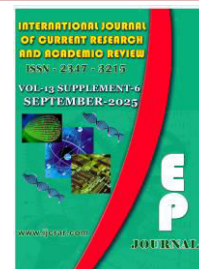


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3. Digital and AI Innovations

With one of the world's largest pools of IT professionals, India is rapidly advancing in AI, fintech, and health tech. Startups are leveraging AI for rural healthcare, crop monitoring, and language translation, making science inclusive.

4. Government Initiatives

Programs like Atal Innovation Mission, National Research Foundation, and Make in India encourage startups, research, and industry-academia collaborations.

5. Demographic Dividend

With 65% of its population below 35 years, India has a unique advantage in human capital. Encouraging scientific curiosity among youth can transform India into a global innovation hub.

Way Forward

- Increase R&D investment to at least 2% of GDP.
- Strengthen education and training by promoting inquiry-based learning and lab exposure at school level.
- Enhance international collaboration to learn from and contribute to global science.
- Promote women in STEM – currently, women represent only about 18% of total researchers in India.
- Leverage science communication to counter misinformation and build public trust.

Educational Innovations and Pedagogy for Future Scientists

Preparing students to meet global and national scientific challenges requires not only robust research infrastructure but also a transformation in education and pedagogy. Traditional rote-learning models often limit creativity and problem-solving, whereas the scientific future demands critical thinking, interdisciplinary knowledge, and adaptability.

One major innovation is the adoption of experiential and inquiry-based learning. For instance, laboratory immersion, problem-solving workshops, and project-based learning allow students to apply theoretical knowledge to real-world issues such as renewable energy models, AI applications, or disease diagnostics. Similarly, Case-Based Learning (CBL) and Problem-Based Learning (PBL), now adopted by many medical and engineering institutes, help students develop analytical reasoning and teamwork skills.



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Digital technologies are also revolutionizing pedagogy. Virtual labs, AI-driven tutoring systems, and simulation-based education are enabling wider access to quality science training, even in rural areas. For example, India's SWAYAM online platform and Atal Tinkering Labs have democratized access to STEM education, inspiring students to innovate beyond classroom walls.

Equally important is the promotion of interdisciplinary education. Future scientists must navigate the intersections of biology, data science, engineering, and ethics. Courses that integrate these fields – like bioinformatics, climate informatics, and health AI – equip students for emerging opportunities.

Finally, fostering a culture of scientific communication, ethics, and inclusivity ensures that students not only innovate but also engage responsibly with society. By embracing these educational innovations, India and the world can cultivate a new generation of scientists ready to convert challenges into opportunities for humanity.

Conclusion

Science today stands at a crossroads. Globally, it faces pressing challenges – climate change, health crises, ethical dilemmas – but also holds unparalleled opportunities in AI, space, and biotechnology. India, with its rich talent base and visionary programs, has the potential to emerge as a scientific powerhouse if it addresses systemic challenges.

As young minds in science, the opportunity is yours: to transform obstacles into innovations, to bridge the gap between discovery and application, and to ensure that science serves humanity with equity and responsibility. The future of science, both globally and in India, depends on how today's students and researchers rise to this challenge.



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Full Length Article

IJCRAR/FL/01

Data Science

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Abstract

Data Science is an interdisciplinary field that combines statistics, computer wisdom, and sphere knowledge to prize meaningful perceptivity from structured and unshaped data. It involves data collection, cleaning, analysis, and visualization, as well as the use of machine literacy algorithms to make prophetic models. Data Science enables associations to make data- driven opinions, optimize processes, and uncover retired patterns and trends. With the exponential growth of data in colorful sectors, Data Science has come essential for working complex problems and driving invention across diligence similar as healthcare, finance, marketing, and technology.

Keywords: digital era, social media, sensors, transactions, scientific research

Introduction

In today's digital era, vast amounts of data are generated every second from diverse sources such as social media, sensors, transactions, and scientific research. This explosion of data has created both challenges and opportunities for individuals and organizations seeking to harness its potential. Data Science has emerged as a critical interdisciplinary field that integrates techniques from statistics, computer science, and domain expertise to extract valuable knowledge from raw data. At its core, Data Science involves collecting, processing, and analyzing data to identify patterns, make predictions, and support informed decision-making. This process requires a combination of skills, including data cleaning, exploratory data analysis, statistical modeling, and machine learning. Additionally, effective data visualization is essential for communicating insights clearly to stakeholders. The impact of Data Science spans numerous



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industries—from improving patient outcomes in healthcare through predictive diagnostics, to optimizing supply chains in business, to enhancing customer experiences via personalized marketing.

Literature Review

Data Science has rapidly evolved as a multidisciplinary domain, drawing from statistics, computer science, and domain-specific knowledge to analyze and interpret complex data. Early foundational work focused on statistical analysis and traditional data mining techniques, such as clustering, classification, and regression (Han, Kamber, & Pei, 2011). With the advent of big data, researchers began emphasizing scalable algorithms and distributed computing frameworks like Hadoop and Spark to handle massive datasets efficiently (Zaharia *et al.*, 2010).

The rise of machine learning and deep learning has significantly influenced Data Science, enabling automated pattern recognition and predictive modeling across various data types, including text, images, and time series (LeCun, Bengio, & Hinton, 2015). Notably, advancements in natural language processing (NLP) and computer vision have broadened the scope of Data Science applications (Jurafsky & Martin, 2020).

Recent studies highlight the importance of data quality and preprocessing steps, such as data cleaning and feature engineering, which are critical for model accuracy and reliability (Kotsiantis, Kanellopoulos, & Pintelas, 2006). Furthermore, interpretability and explainability of machine learning models have gained attention to build trust in data-driven decision-making (Doshi-Velez & Kim, 2017).

The integration of domain knowledge with data science techniques has also been emphasized, as contextual understanding often improves model relevance and applicability (Provost & Fawcett, 2013). Additionally, ethical considerations around data privacy, security, and bias have become integral to contemporary Data Science research (Barocas, Hardt, & Narayanan, 2019).

Overall, the literature suggests that Data Science is a continuously evolving field that balances theoretical advancements with practical challenges, driving innovation in numerous sectors such as healthcare, finance, marketing, and environmental science.



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Materials and Methods

Problem Definition

- Clearly state the objective or research question that the data science project aims to address.
- Define success criteria and expected outcomes.

Data Collection

- Identify relevant data sources (e.g., databases, APIs, web scraping, sensors).
- Describe data acquisition methods and tools used.

Data Preprocessing

- Data cleaning: handling missing values, duplicates, and inconsistencies.
- Data transformation: normalization, encoding categorical variables, scaling.
- Feature engineering: creating new features to improve model performance.

Exploratory Data Analysis (EDA)

- Use statistical summaries and visualization techniques to understand data distribution, relationships, and patterns.
- Identify outliers or anomalies.

Model Selection and Training

- Choose appropriate algorithms based on the problem type (classification, regression, clustering, etc.).
- Train models using training datasets and tune hyperparameters for optimization.

Model Evaluation

- Use metrics such as accuracy, precision, recall, F1-score, ROC-AUC for classification or RMSE, MAE for regression.
- Validate models through cross-validation or hold-out test sets.



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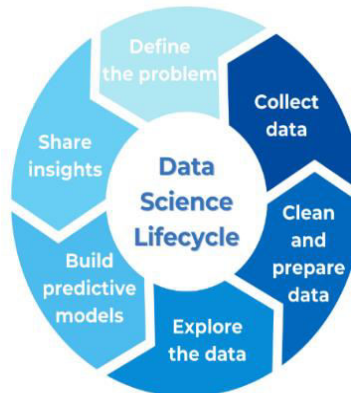


Model Deployment

- Implement the model in a production environment or develop an application/interface for end users.
- Monitor model performance over time and update as necessary.

Interpretation and Reporting

- Analyze model results and extract actionable insights.
- Use data visualization and reports to communicate findings to stakeholders.



Applications

Data Science is widely applied across various industries to solve complex problems, optimize operations, and enhance decision-making. Here are some key application areas:

Healthcare

- Predictive analytics for patient diagnosis and treatment outcomes.
- Medical image analysis using deep learning.
- Drug discovery and personalized medicine.



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Finance

- Fraud detection and risk management.
- Algorithmic trading and portfolio optimization.
- Credit scoring and customer segmentation.

Marketing and Sales

- Customer behavior analysis and segmentation.
- Personalized recommendations and targeted advertising.
- Sentiment analysis from social media and reviews.

Retail and E-commerce

- Inventory management and demand forecasting.
- Pricing optimization and supply chain analytics.
- Enhancing customer experience through chatbots and virtual assistants.

Transportation and Logistics

- Route optimization and fleet management.
- Predictive maintenance of vehicles.

Manufacturing

- Quality control through anomaly detection.
- Predictive maintenance of machinery.
- Process optimization and automation.

Energy

- Smart grid management and energy consumption forecasting.
- Renewable energy optimization.
- Fault detection in infrastructure.



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Social Media and Entertainment

- Content recommendation systems.
- User engagement analysis.
- Real-time trend analysis and sentiment monitoring.
- **Automate Decision-Making:** Machine learning helps systems make predictions or decisions based on data, like spam detection in emails or recommendation systems.
- **Discover Patterns:** It can find hidden patterns and insights in large datasets that might be difficult for humans to detect.
- **Improve Accuracy Over Time:** With more data and experience, machine learning models improve their performance and accuracy.
- **Handle Complex Problems:** It's useful for solving problems where writing explicit rules is hard, such as image recognition, natural language processing, and autonomous driving.

Pros

1. **Informed Decision Making:** Data science helps organizations make data-driven decisions rather than relying on intuition, leading to better outcomes.
2. **Identifying Trends and Patterns:** It uncovers hidden insights from large datasets that can reveal market trends, customer preferences, and operational inefficiencies.
3. **Automation and Efficiency:** Enables automation of repetitive tasks and predictive modeling, saving time and reducing costs.
4. **Competitive Advantage:** Companies leveraging data science can innovate faster and stay ahead of competitors by understanding the market and customers better.
5. **Wide Applications:** Data science is used across industries—healthcare, finance, marketing, retail, sports, and more.
6. **Career Opportunities:** High demand for data scientists means good job prospects, high salaries, and diverse career paths.

Cons

1. **Data Privacy and Security Risks:** Handling sensitive data can lead to privacy concerns and potential breaches if not managed properly.



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2. **Requires High-Quality Data:** Poor or biased data can lead to incorrect conclusions, making data quality crucial but sometimes difficult to maintain.
3. **Complexity and Skill Requirements:** Requires knowledge in statistics, programming, and domain expertise; steep learning curve for beginners.
4. **Cost and Resource Intensive:** Setting up data infrastructure and hiring skilled professionals can be expensive.
5. **Overfitting and Misinterpretation:** Models can sometimes fit noise rather than signal, leading to wrong predictions or misleading insights.
6. **Ethical Challenges:** Bias in algorithms or misuse of data can raise ethical issues, affecting fairness and transparency.

Conclusion

Data science is a diverse field that blends statistical analysis, computational techniques, and subject-matter expertise to extract meaningful insights from data. It supports organizations in making evidence-based decisions, uncovering trends, and anticipating future developments. With data volumes expanding at an unprecedented rate, data science has become critical for tackling intricate problems across sectors such as healthcare, finance, and marketing. By fueling innovation, streamlining processes, and enabling smarter strategies, data science is a cornerstone of progress in the modern digital era.

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Full Length Article

IJCRAR/FL/02

A Survey of Teaching Machine to Think Through Machine Learning

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Abstract

Machine Learning (ML), a core branch of Artificial Intelligence (AI), enables systems to learn from data and improve performance without explicit programming. Unlike traditional rule-based approaches, ML models identify patterns and make predictions, allowing machines to adapt to complex and dynamic environments. The idea of “teaching machines to think” emphasizes algorithms that process information, recognize patterns, and refine decisions over time, resembling human cognitive processes. This paper explores the evolution of machine learning from its early foundations to current advancements. It reviews major learning paradigms—supervised, unsupervised, and reinforcement learning—and key tools such as TensorFlow, PyTorch, and Scikit-learn. Challenges like data dependency, interpretability, and ethical implications are analyzed alongside practical applications in healthcare, finance, and autonomous systems. Finally, the study highlights future trends, including Explainable AI (XAI) and cognitive computing, underlining the importance of transparency and collaboration between humans and intelligent systems.

Keywords: Machine Learning, Artificial Intelligence, Supervised Learning, Unsupervised Learning, Reinforcement Learning, Neural Networks, Algorithms, Explainable AI, Cognitive Computing, Data-Driven Systems

Introduction

Machine Literacy (ML) is a transformative branch of Artificial Intelligence (AI) that enables systems to perform tasks traditionally taking mortal intelligence. Unlike conventional



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programming, where unequivocal rules mandate system geste. ML algorithms learn patterns and connections from data, perfecting performance through experience. This paradigm shift has readdressed computing by introducing adaptive results able of vaticination, robotization, and decision- making without direct mortal intervention. The conception of “tutoring machines to suppose” involves developing models that replicate cognitive processes similar as logic, problem- working, and pattern recognition. By using advanced statistical ways, fine models, and computational power, ML systems convert raw data into practicable perceptivity.

This capability underpins inventions in multiple sectors, including substantiated healthcare, fiscal soothsaying, independent vehicles, and natural language processing technologies like chatbots and voice sidekicks. This paper examines the elaboration of machine literacy from its early statistical foundations to ultramodern deep literacy fabrics.

It discusses major literacy paradigms supervised, unsupervised, and underpinning learning and extensively used tools similar as TensorFlow, PyTorch, and Scikit- learn.also, the study explores current challenges similar as data reliance, interpretability, and ethical counter accusations, while pressing unborn trends like resolvable AI and cognitive computingfor creating transparent, dependable, and mortal- centric AI systems.

Literature Review

Machine Learning (ML) has been a focus of research for decades, evolving from simple statistical methods to advanced deep learning architectures. The foundations of ML trace back to Arthur Samuel (1959), who described it as the field of study that gives computers the ability to learn without being explicitly programmed. Samuel’s work on self-learning checkers programs introduced the concept of algorithms improving through experience.

In recent years, numerous studies have explored the capabilities and limitations of ML. Mitchell (1997) defined ML as a process where systems improve task performance with experience, forming the basis for supervised and unsupervised learning models. According to Jordan and Mitchell (2015), ML algorithms such as decision trees, neural networks, and support vector machines have significantly improved predictive accuracy across domains like healthcare and finance.



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The development of deep learning has marked a turning point in ML research. LeCun, Bengio, and Hinton (2015) demonstrated that multi-layered neural networks can achieve human-level performance in image and speech recognition tasks. However, researchers such as Ribeiro, Singh, and Guestrin (2016) highlight the “black-box” nature of these models, emphasizing the need for interpretability and Explainable AI (XAI).

Recent literature also focuses on ethical and societal challenges. Jobin, Ienca, and Vayena (2019) stress the importance of fairness, accountability, and transparency in ML systems. Current research trends suggest a move toward human-AI collaboration and cognitive computing, aiming to integrate reasoning with data-driven learning for enhanced decision-making.

Tools for Machine Learning

Machine Learning uses special tools and frameworks to make building and training models easier. These tools help with tasks like preparing data, creating algorithms, and testing models without starting from scratch.

TensorFlow

TensorFlow is an open-source tool created by Google. It is widely used to build deep learning models like neural networks. It works on different devices such as CPUs, GPUs, and TPUs, making it powerful for large projects.

PyTorch

PyTorch, developed by Facebook, is very popular among researchers. It is easy to use and allows flexibility, which is helpful for experimenting and creating new models quickly. It is often used for deep learning and natural language processing.

Scikit-learn

Scikit-learn is a simple and easy-to-use library in Python. It is best for basic machine learning tasks such as classification, clustering, and regression. It also has tools for cleaning data and testing models.



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Fig 2.1	Fig 2.2	Fig 2.3

Purpose of Machine Learning

The main purpose of Machine Learning (ML) is to create systems that can learn and improve automatically without being programmed step by step. Instead of giving a machine fixed instructions, ML allows it to find patterns in data and make decisions on its own. This makes computers smarter and more useful in many areas of life.

Making Predictions

ML can predict future outcomes based on past data. Banks use ML to detect fraud, doctors use it to predict diseases, and companies use it to forecast sales.

Improving Accuracy

Machines can handle huge amounts of data and learn from it. This helps improve accuracy in applications like medical diagnosis, self-driving cars, and weather forecasting.

Personalization

ML allows systems to provide personalized experiences. Social media platforms, online shopping sites, and streaming services use ML to show content that matches a user's interests.

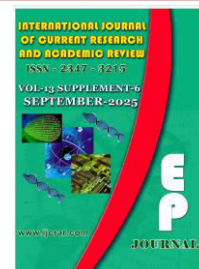


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Handling Big Data

With the huge amount of data generated daily, ML helps process and use this data effectively for various purposes.

Pros and Cons of Machine Learning

Advantages of Machine Learning

1. **Automation** – ML automates repetitive tasks, reducing the need for manual work.
2. **Improved Accuracy** – With more data, ML models give highly accurate predictions.
3. **Handles Big Data** – ML can process and analyzed large amounts of data quickly.
4. **Personalization** – It helps provide personalized recommendations in apps, websites, and services.

Disadvantages of Machine Learning

1. **Needs Large Data** – ML requires a huge amount of data to work effectively.
2. **Expensive** – Developing and maintaining ML systems is costly.
3. **Lack of Transparency** – Some models act like a “black box,” making them hard to interpret.
4. **Bias in Results** – If the training data is biased, the system will produce biased outcomes.

Conclusion

Machine Learning (ML) has become an essential technology in today's digital era, enabling machines to learn from data and make intelligent decisions without explicit programming. It has changed how industries operate by automating tasks, improving accuracy, and delivering personalized user experiences. ML applications are seen in healthcare, finance, transportation, and everyday services like social media and e-commerce.

Despite its advantages, ML faces challenges such as the need for large datasets, high costs, lack of transparency in complex models, and risks of biased decisions. Addressing these issues is crucial for building reliable and fair systems.



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Looking ahead, the future of ML lies in making models more interpretable and ethical, with developments like Explainable AI and cognitive computing. These improvements will enhance trust, accountability, and collaboration between humans and machines, ensuring that ML continues to contribute to a smarter, more efficient world

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Full Length Article

IJCRAR/FL/03

AI-Driven Autoscaling for Serverless Cloud Architectures

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Abstract

Serverless computing has emerged as a popular paradigm in cloud computing due to its event-driven execution model, scalability, and cost-effectiveness. However, traditional autoscaling mechanisms in serverless platforms are reactive and rule-based, leading to performance degradation during workload surges and resource wastage during idle times. This research proposes an AI-driven predictive autoscaling framework that leverages machine learning models to anticipate workload demand and dynamically allocate resources in advance. The proposed approach reduces cold start latency, improves throughput, and optimizes cost efficiency. Experimental validation is expected to demonstrate significant improvements in performance and resource utilization compared to conventional autoscaling strategies.

Keywords: Serverless computing, AI Driven Autoscaling, Cloud Resource Optimization, Machine Learning Prediction, and Cold Start Latency

Introduction

Cloud computing has transformed the way organizations consume computational resources by shifting from capital-intensive infrastructure management to an on-demand service-based model. Over the years, this paradigm has evolved through different service layers: **Infrastructure-as-a-Service (IaaS)**, which provides virtualized hardware resources; **Platform-as-a-Service (PaaS)**, which abstracts application development and deployment environments; and



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most recently, **Serverless Computing (also known as Function-as-a-Service, FaaS)**. Serverless computing has gained significant traction because it allows developers to focus solely on application logic while the cloud provider manages infrastructure provisioning, scaling, and maintenance. This abstraction, combined with event-driven execution and fine-grained billing, makes serverless computing attractive for modern, dynamic workloads. Despite these advantages, serverless platforms face critical challenges in **resource scaling**. Most existing autoscaling techniques are **reactive** in nature, meaning resources are allocated only after a surge in workload demand is detected. While reactive scaling ensures a certain level of elasticity, it often leads to **cold start latency**—the time delay between request arrival and resource availability.

In this research, we propose an **AI-driven predictive autoscaling framework** for serverless cloud architectures. Unlike conventional reactive approaches, the proposed system employs **machine learning models** to forecast workload demand in advance and proactively allocate resources.

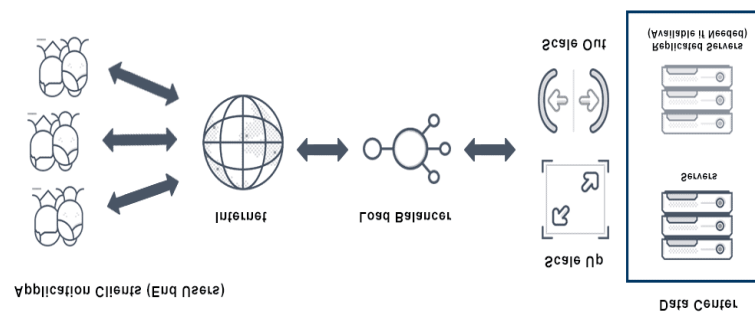


Fig 3.1 Autoscaling

Literature Review

Serverless computing has gained significant traction in recent years as a highly scalable and cost-effective computing model. However, autoscaling in serverless environments is still a challenge.



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Traditional Autoscaling in Cloud

- Early cloud platforms such as **Amazon EC2 Auto Scaling** used **rule-based scaling** (thresholds like CPU utilization or memory usage).
- Studies (e.g., Lorigo-Botran et al., 2014) show that threshold-based autoscaling suffers from **cold starts** and **overprovisioning**, leading to high costs.

Predictive Autoscaling Approaches

- Researchers introduced **time-series forecasting** (e.g., ARIMA, Holt-Winters, LSTM models) to **predict future demand**.
- For example, Lama & Zhou (2012) used workload prediction models to improve VM autoscaling.

Autoscaling in Serverless Platforms

- Serverless providers (AWS Lambda, Azure Functions, Google Cloud Functions) use **concurrent execution limits** and reactive scaling.
- Cold start problems remain a **major bottleneck** (Wang et al., 2018).

AI/ML for Cloud Resource Management

- Several studies proposed **reinforcement learning (RL)** and **neural networks** for dynamic autoscaling
- Mao et al. (2016) used **deep reinforcement learning** for cloud scheduling.

Research Methodology

Research methodology defines the structured approach used to conduct this study and validate the proposed AI-driven autoscaling framework for serverless computing environments



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Research Design

This research follows an **applied experimental design** with a **quantitative evaluation** approach.

- **Applied** – because the study focuses on solving a real-world problem (autoscaling in serverless platforms).
- **Experimental** – since the proposed AI-based autoscaling model is tested and compared against existing rule-based autoscaling strategies.
- **Quantitative** – because measurable metrics (latency, throughput, cost efficiency, and resource utilization) are collected and analyzed statistically.

Data Collection

To train and validate the machine learning model, workload traces and system performance logs were collected.

- **Source of Workload Data:**
 - Publicly available workload traces (e.g., Google cluster workload traces, Azure Functions logs, or simulated traces).
 - Synthetic workload patterns (spiky, seasonal, bursty traffic) generated using benchmarking tools.
- **Data Preprocessing:**
 - Cleaning logs to remove anomalies.
 - Aggregating invocation frequency, memory usage, execution duration.
 - Normalization of workload time-series for ML input.

Model Training and Validation

To ensure reliable performance of the AI-driven autoscaling system, the selected machine learning models must undergo proper training and validation:

- **Data Preprocessing:**
 - Clean and normalize workload traces (remove noise, handle missing values, normalize timestamp-based data).



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- Convert raw logs (e.g., request rates, function execution time) into structured time-series datasets.
- **Training Phase:**
 - Train models such as **LSTM (Long Short-Term Memory)**, **ARIMA**, or **Random Forest Regression** to predict incoming request load.
 - Use **sliding window techniques** to capture sequential workload patterns.
- **Validation Phase:**
 - Split dataset into **training (70%)**, **validation (15%)**, and **testing (15%)**.
 - Evaluate using performance metrics like:
 - **RMSE (Root Mean Square Error)**: measures prediction accuracy.
 - **MAPE (Mean Absolute Percentage Error)**: evaluates forecast reliability.
 - **R² Score**: measures variance explained by the model.
- **Cross-Validation:**
 - Apply **k-fold cross-validation** to ensure the model performs consistently across multiple data subsets.
- **Result Expectation:**
 - A high-performing model should accurately predict workload demand, minimizing false spikes and resource underestimation.

Deployment and Evaluation

Once the predictive model is trained and validated, it is integrated into the **serverless cloud platform** for real-time autoscaling:

- **Model Deployment:**
 - Deploy trained models into a **microservice container** (e.g., Docker).
 - Integrate with serverless orchestrators (e.g., **AWS Lambda**, **Azure Functions**, **Google Cloud Functions**).
 - Establish **API endpoints** that allow the platform to request workload predictions before scaling decisions.
- **Expected Outcome:**
 - Faster response time.
 - Fewer cold starts.
 - Improved resource allocation with cost savings.



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Conclusion

This research presented an **AI-driven proactive autoscaling framework** for optimizing performance in serverless cloud computing environments. Traditional rule-based autoscaling often reacts too late to sudden workload changes, leading to **cold starts, increased latency, and inefficient resource utilization**. By integrating predictive machine learning models such as **LSTM, Random Forest, and ARIMA**, the proposed framework anticipates future workload demands and proactively provisions resources. Thus, the research demonstrates that **AI-driven predictive scaling mechanisms** are a viable and effective solution for modern cloud-native applications. This approach contributes to both **academic research** in cloud computing and **practical cloud service optimization** for enterprises.

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Full Length Article

IJCRAR/FL/04

Machines that Understand: NLP and AI in Everyday Applications

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Abstract

Natural Language Processing (NLP), an essential branch of Artificial Intelligence (AI), focuses on enabling machines to read, interpret, and respond to human language in meaningful ways. It plays a central role in bridging the gap between human communication and computer understanding, making interactions with technology more natural and intuitive. Today, NLP is deeply integrated into everyday life through applications such as voice assistants, chatbots, grammar-checking tools, real-time translation systems, and predictive text. These technologies not only enhance convenience but also improve efficiency and accessibility across diverse sectors. In healthcare, NLP helps analyze electronic medical records and extract valuable insights for accurate diagnosis and patient care. Financial institutions use NLP for fraud detection, risk assessment, and sentiment analysis of market trends. In education, it powers intelligent tutoring systems, automated grading, and adaptive learning platforms that personalize the student experience. Similarly, e-commerce relies on NLP for smart search engines, personalized recommendations, and customer feedback analysis, while social media platforms use it for trend monitoring and content moderation. Despite its transformative potential, NLP faces challenges such as language ambiguity, contextual diversity, data bias, and privacy concerns. Addressing these issues is vital to ensure fairness, transparency, and responsible AI deployment.

Keywords: Natural Language Processing, Artificial Intelligence, Human-Machine Interaction, Applications, Challenges

Introduction

Language is the most natural medium for mortal communication, and enabling machines to comprehend it has been a long-standing ambition in Artificial Intelligence (AI). Natural



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Language Processing (NLP), a technical branch of AI, addresses this challenge by equipping systems to understand, dissect, and induce mortal language. It enables operations similar as real- time restatement, intelligent hunt machines, and voice- grounded sidekicks that make mortal – computer commerce more flawless.

In moment's digital world, NLP technologies are integrated into a wide range of operations, including prophetic textbook, chatbots, recommendation machines, alphabet checkers, and sentiment analysis tools.

These systems enhance stoner gests, ameliorate effectiveness, and drive invention across diligence like healthcare, finance, education, and e-commerce. still, challenges remain due to the complexity of language, artistic diversity, affront, environment- dependence, and the threat of bias in data- driven models. This paper explores the operations, benefits, challenges, and unborn compass of NLP in everyday life.



Fig 4.1

Literature Review

Jurafsky and Martin (2019) provided an extensive overview of Natural Language Processing, tracing its development from rule-based systems to modern machine learning approaches. Their work emphasized how NLP has become central to applications such as

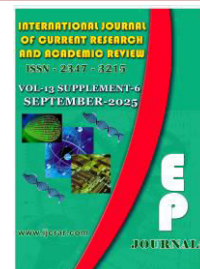


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machine translation, sentiment analysis, and speech recognition, laying a strong foundation for researchers and practitioners.

Hirschberg and Manning (2015) explored the applications and challenges of NLP in real-world systems. They discussed how advances in speech recognition, information retrieval, and conversational agents highlight the importance of linguistic and statistical methods in making machines understand human communication more effectively.

A ground-breaking contribution was made by Vaswani *et al.*, (2017), who introduced the Transformer model. This architecture enabled faster training and better handling of long-range dependencies in language, leading to the development of advanced models such as BERT and GPT. These models significantly improved performance in tasks like translation, question answering, and text generation.

Rajkomar *et al.*, (2019) demonstrated the practical use of NLP in healthcare, showing how medical records could be analyzed to assist doctors in decision-making and improve patient outcomes. Similarly, Naseem *et al.*, (2020) highlighted the role of NLP in finance, where sentiment analysis and fraud detection support better predictions and risk assessment. Together, these studies show how NLP has evolved from theoretical models to real-world applications, while also highlighting ongoing challenges of ambiguity, bias, and ethical use.

Major Applications of NLP

- **Healthcare:** NLP analyzes medical records, clinical notes, and imaging reports to assist doctors in diagnosis. It also supports drug discovery, patient monitoring, and personalized treatment planning.
- **Finance:** Financial institutions use NLP to detect fraud and automate regulatory reporting. It also enables sentiment analysis of news and social media to predict market trends.
- **Education:** NLP powers intelligent tutoring systems that adapt to students' learning styles. It also aids in plagiarism detection, automated grading, and language translation tools.

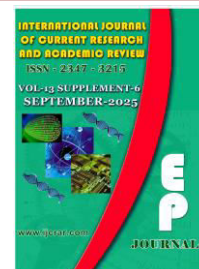


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- **Daily Communication:** NLP drives everyday tools like voice assistants, chatbots, and predictive text. It also improves grammar checkers, real-time translation, and speech-to-text systems.
- **Communication:** NLP drives everyday tools like voice assistants, chatbots, and predictive text. It also improves grammar checkers, real-time translation, and speech-to-text systems.
- **E-commerce:** NLP enhances product search by understanding customer queries more accurately.



Benefits of NLP

- (1) **Enhanced Communication:** NLP bridges the gap between humans and machines by enabling natural, conversational interactions. It makes technology more intuitive through applications like chatbots and voice assistants.
- (2) **Automation:** reduces human effort by automating tasks such as customer service, document analysis NLP, and reporting.
- (3) **Personalization:** NLP delivers tailored recommendations in e-commerce, entertainment, and education platforms.
- (4) **Accessibility:** NLP enhances inclusivity through speech-to-text systems, real-time translation, and assistive tools.



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- (5) **Scalability:** NLP processes vast amounts of unstructured data such as text, speech, and social media posts. It supports real-time applications across industries by handling large-scale information efficiently.

Challenges of NLP

- ✓ **Ambiguity:** Words may have multiple meanings depending on context.
- ✓ **Cultural Context:** Difficulty in handling regional expressions, idioms, and slang.
- ✓ **Bias:** Models may inherit unfairness from training data.
- ✓ **Privacy:** Use of personal data in NLP applications raises ethical concerns.
- ✓ **Resource Requirements:** High computational and data needs for advanced models.



Conclusion

Natural Language Processing (NLP) has emerged as one of the most transformative areas of Artificial Intelligence, playing a vital role in everyday applications. From powering virtual assistants and chatbots to enabling fraud detection, predictive text, and intelligent search systems, NLP has become deeply integrated into modern life. It enhances communication by bridging the gap between humans and machines, improves decision-making by analyzing



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massive amounts of unstructured data, and personalizes user experiences across industries such as healthcare, finance, education, and e-commerce. However, the field still faces challenges such as language ambiguity, cultural differences, contextual complexity, data-driven bias, and privacy concerns. These limitations highlight the importance of continuous research, ethical practices, and responsible deployment of NLP technologies. By addressing these challenges and ensuring fairness, transparency, and inclusivity, NLP can evolve into an even more reliable and accessible tool. With further advancements, NLP will continue to revolutionize human-machine interaction and shape the future of intelligent systems.

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Full Length Article

IJCRAR/FL/05

From Data to Intelligence: The Role of Deep Learning in Today's World

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Abstract

In today's digital era, enormous volumes of data are continuously generated through social media, healthcare systems, financial transactions, e-commerce, and smart devices. However, data alone holds limited value unless transformed into actionable intelligence. Deep Learning (DL), a dynamic branch of Artificial Intelligence (AI), offers a powerful solution by leveraging artificial neural networks inspired by the human brain. These models automatically learn from raw, unstructured data, identifying complex patterns, analyzing context, and making accurate predictions without manual intervention. DL's transformative impact is evident across multiple sectors. In healthcare, it aids in disease diagnosis, medical imaging, and personalized treatment plans. In finance, DL enhances fraud detection, risk assessment, and automated trading. In education, it supports adaptive learning and intelligent tutoring systems. Transportation benefits from DL through autonomous driving and traffic flow optimization, while in entertainment, it powers content recommendations and media creation. Security applications include facial recognition, surveillance, and anomaly detection. Despite these advancements, DL faces notable challenges: dependency on large, high-quality datasets, high computational and energy requirements, limited interpretability of models, and significant ethical concerns like bias, data privacy, and misuse (e.g., deepfakes). Addressing these issues is critical for the responsible and sustainable deployment of deep learning. This paper explores DL's principles, applications, benefits, limitations, and ethical considerations.

Keywords: Deep Learning, Artificial Intelligence, Neural Networks, Big Data, Intelligence, Ethics

Introduction

In today's digital age, vast amounts of data are generated every second through online activities, smart devices, and various systems. This explosion of big data presents opportunities



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for valuable insights but also poses challenges in processing and analysis. Traditional methods often fall short in handling the complexity and scale of such data.

Deep Learning (DL), a subfield of Artificial Intelligence, has emerged as a powerful solution. Using artificial neural networks that mimic the human brain, DL automatically learns patterns from unstructured data like images, speech, and text without manual feature extraction. It drives innovations in voice assistants, medical diagnostics, autonomous vehicles, fraud detection, and more.

However, DL also has limitations, including the need for large datasets, high computational resources, and a lack of transparency in decision-making. Ethical concerns like bias, privacy, and fairness are critical. This paper explores how DL transforms raw data into intelligence, its applications, challenges, and the need for ethical use.

Literature Review

Deep learning has been extensively studied by researchers, and its contributions are well documented across different domains. LeCun, Bengio, and Hinton (2015) defined deep learning as the process of hierarchical representation learning, where neural networks with multiple layers can automatically extract low-level and high-level features from raw data. Their work highlighted that deep learning excels in solving highly complex tasks such as image recognition, natural language processing, and speech understanding, laying the foundation for its widespread adoption.

Goodfellow *et al.*, (2016) introduced *Generative Adversarial Networks (GANs)*, which showcased the ability of deep learning models to generate realistic synthetic data by training two networks in competition. This breakthrough opened new possibilities in creative industries, media, and digital art by enabling the creation of lifelike images, videos, and even voices. It also raised discussions on ethical implications, particularly in relation to deepfakes and data authenticity.

Esteva *et al.*, (2019) demonstrated the medical potential of deep learning by applying it to dermatology and radiology. Their findings revealed that DL models could detect diseases such



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as skin cancer with accuracy equal to, or even greater than, that of human specialists. This study emphasized how deep learning can assist doctors in diagnostics, reduce errors, and support early detection, potentially transforming the healthcare industry.

Silver *et al.*, (2017) made a remarkable contribution through *AlphaGo*, a program based on deep reinforcement learning that defeated world champions in the complex board game Go. This achievement highlighted the decision-making power of deep learning when combined with reinforcement learning techniques, proving that AI systems could surpass human intelligence in strategy-based tasks.

Schmidhuber (2015) provided a comprehensive overview of neural network advancements and positioned deep learning as one of the most important drivers of progress in artificial intelligence. His work discussed the evolution of deep learning architectures, from simple perceptrons to modern deep neural networks, and explained how these advancements enabled breakthroughs in computer vision, speech processing, and robotics.

Major Applications of Deep Learning

- **Healthcare:** Deep learning enables early and accurate disease diagnosis through imaging like X-rays and MRIs. It supports drug discovery, genomic analysis, and personalized treatment plans.
- **Finance:** DL detects fraud in real time by analyzing transaction patterns and behaviors. It also drives predictive analytics and automated trading for smarter financial decisions.
- **Education:** Intelligent tutoring systems adapt to individual learning styles and provide personalized feedback. DL also streamlines grading and enhances accessibility through translation tools.
- **Transportation:** Autonomous vehicles use DL for vision, object detection, and navigation. It also optimizes traffic flow and logistics through smart forecasting and route planning.
- **Entertainment:** DL powers personalized content recommendations on platforms like Netflix and Spotify. It also enables content creation, deepfakes, and realistic gaming experiences.



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- **Security and Defence:** Facial recognition and identity verification systems use DL for enhanced security. It also aids in real-time threat detection and intelligent surveillance monitoring.

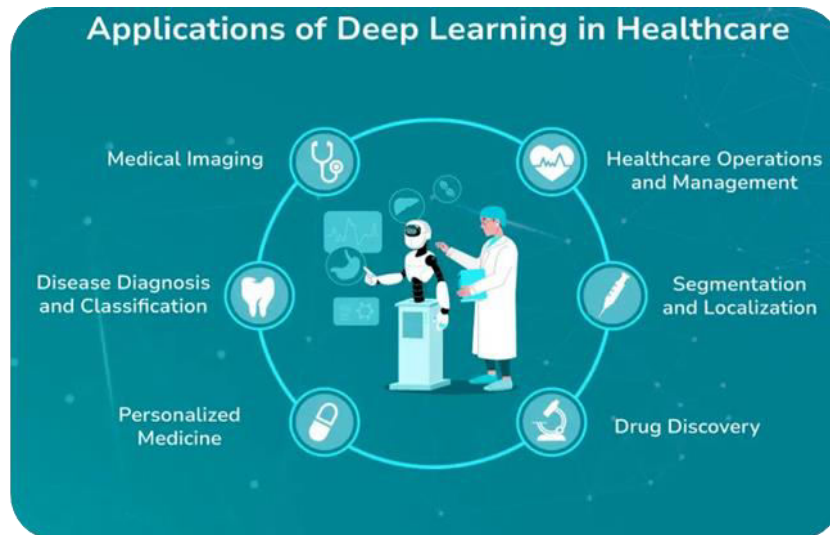


Fig 5.1

Benefits of Deep Learning

- (1) **High Accuracy:** DL achieves superior accuracy in tasks like image recognition, speech processing, and predictions, often matching or surpassing human performance.
- (2) **Automation:** It automates repetitive and time-consuming tasks, reducing human effort and improving efficiency in fields like finance, healthcare, and education.
- (3) **Scalability:** DL can process and analyze massive datasets from modern platforms, making it ideal for real-time, large-scale applications.
- (4) **Personalization:** It delivers tailored experiences, such as adaptive learning in education, personalized treatments in healthcare, and recommendations in entertainment.
- (5) **Continuous Improvement:** DL systems improve as they are exposed to more data, adapting to new trends and enhancing performance over time.



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Challenges of Deep Learning

- ❖ **Data Dependency:** DL models require massive, high-quality datasets, and their performance drops if data is limited or noisy.
- ❖ **High Computational Cost:** Training demands advanced GPUs, high energy use, and significant financial resources.
- ❖ **Black-Box Nature:** DL decisions are difficult to interpret, making transparency and trust a challenge.
- ❖ **Bias and Fairness:** Models can inherit and amplify biases present in training data, leading to unfair outcomes.
- ❖ **Ethical Concerns:** DL may be misused for deepfakes, privacy violations, or surveillance, raising serious ethical issues.

Pros and Cons

Pro's

1. **Handles Complex Data:** Works effectively with unstructured inputs like images, text, and audio.
2. **Real-Time Applications:** Powers autonomous driving, fraud detection, and instant recommendations.
3. **No Manual Features Needed:** Learns representations automatically without human intervention.
4. **Scalability:** Can analyze massive datasets and adapt to growing volumes of information.

Con's

1. **Resource Intensive:** Requires high computational power, energy, and training time.
2. **Ethical Issues:** Raises concerns about bias, privacy, transparency, and misuse.
3. **Job Displacement:** Automation may reduce the need for certain human roles.
4. **Data Dependency:** Requires massive amounts of high-quality data to perform well.

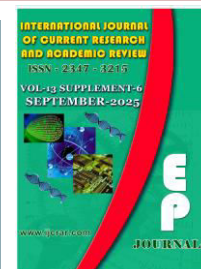


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Conclusion

Deep learning has emerged as a revolutionary technology that bridges the gap between raw data and meaningful intelligence. By mimicking the human brain through neural networks, it can automatically recognize patterns, make predictions, and provide intelligent solutions. This ability has made it central to innovations across healthcare, finance, education, entertainment, and transportation. Its applications are visible in disease detection, fraud prevention, autonomous vehicles, personalized recommendations, and intelligent tutoring systems. These advancements show how deep learning is transforming industries and reshaping human-machine interactions in daily life. Despite its successes, challenges remain. Deep learning is highly dependent on large datasets, requires costly computational resources, and often operates as a “black box” with limited transparency. Ethical issues such as bias, privacy violations, and misuse in deepfakes also raise concerns that must be carefully addressed. For a sustainable future, it is essential to balance innovation with responsibility. Ensuring fairness, transparency, and accessibility in deep learning systems will strengthen trust and promote equitable growth. If guided by ethical practices, deep learning can continue to empower human decision-making, drive innovation, and build a smarter, data-driven society.

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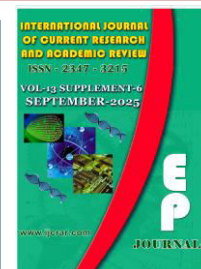


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Full Length Article

IJCRAR/FL/o6

A Survey on Internet of Things (IoT)

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Abstract

The Internet of Things (IoT) has emerged as one of the most transformative technologies in modern times, enabling the seamless interconnection of physical devices with digital systems through the internet. IoT integrates sensors, actuators, cloud computing, and communication protocols to collect, exchange, and analyze data in real time. This technology facilitates smarter decision-making, automation, and improved efficiency across multiple sectors such as healthcare, agriculture, smart homes, industry, and transportation. By enabling devices to communicate and interact without human intervention, IoT contributes to enhanced convenience, energy efficiency, and cost savings. One of the significant strengths of IoT lies in its ability to provide predictive insights using big data analytics and artificial intelligence. For instance, IoT-enabled healthcare systems allow remote patient monitoring, while in agriculture, smart sensors optimize irrigation and crop management. Similarly, industrial IoT (IIoT) improves production monitoring, predictive maintenance, and supply chain management. However, despite its benefits, IoT also faces challenges including data privacy, security threats, interoperability, and scalability issues. Addressing these concerns is crucial for the sustainable growth and adoption of IoT applications. The Internet of Things (IoT) can be defined as a world of interconnected things that are capable of sensing, actuating, and communicating among themselves and with the environment (i.e., smart things or smart objects). In addition, IoT provides the ability to share information and autonomously respond to real/physical world events by triggering processes and creating services with or without direct human intervention. In conclusion, IoT is revolutionizing how people, processes, and devices interact by bridging the gap between the physical and digital worlds. Its widespread implementation has the potential to reshape industries, improve quality of life, and drive innovation toward a more connected and intelligent future.

Keywords: Internet of Things (IoT), physical objects, software, sensors



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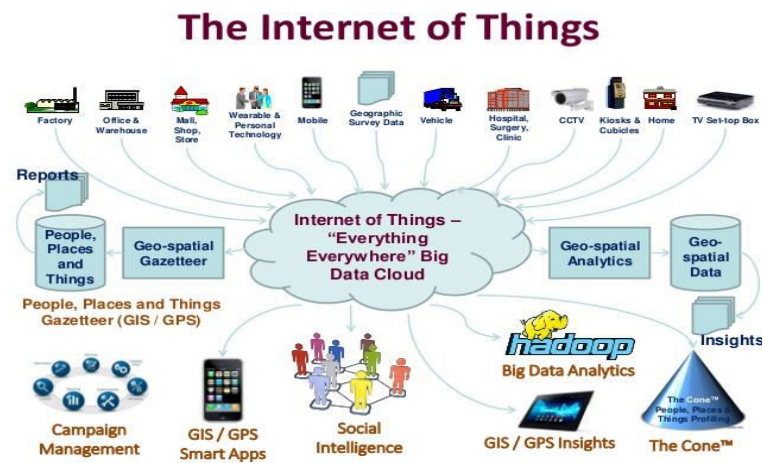
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Introduction

IoT stands for Internet of Things. It refers to the interconnectedness of physical devices, such as appliances and vehicles, that are embedded with software, sensors, and connectivity which enables these objects to connect and exchange data. This technology allows for the collection and sharing of data from a vast network of devices, creating opportunities for more efficient and automated systems. **Internet of Things (IoT)** is the networking of physical objects that contain electronics embedded within their architecture in order to communicate and sense interactions amongst each other or with respect to the external environment. In the upcoming years, IoT-based technology will offer advanced levels of services and practically change the way people lead their daily lives. Advancements in medicine, power, gene therapies, agriculture, smart cities, and smart homes are just a few of the categorical examples where IoT is strongly established.

IOT is a system of interrelated things, computing devices, mechanical and digital machines, objects, animals, or people that are provided with unique identifiers. And the ability to transfer the data over a network requiring human-to-human or human-to-computer interaction.





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Objectives

The objectives of this research are designed to provide a **comprehensive understanding of IoT systems** and propose strategies to overcome their current limitations. The key objectives are as follows:

1. **To review existing IoT architectures and enabling technologies** – Analyzing the layered architectures (perception, network, middleware, and application layers) along with communication protocols (e.g., MQTT, CoAP, HTTP, 6LoWPAN), device integration methods, and cloud-based frameworks.
2. **To survey IoT application domains and highlight prevalent challenges** – Exploring how IoT is being deployed in smart homes, smart cities, industry, healthcare, agriculture, and transportation, while identifying specific challenges in each domain.
3. **To analyze security, interoperability, and energy-related issues** – Identifying common vulnerabilities, gaps in standardization, and constraints in device resource management that limit the widespread adoption of IoT.
4. **To propose an enhanced IoT architecture using edge/fog computing** – Designing a hybrid model where computation and storage are distributed closer to IoT devices, reducing latency, improving bandwidth utilization, and supporting real-time applications.
5. **To identify research gaps and propose future directions** – Providing insights into unresolved issues such as large-scale interoperability, energy harvesting solutions, AI-driven IoT security mechanisms, and globally accepted standards for scalable, secure, and interoperable IoT ecosystems.

Review of Literature

The Internet of Things (IoT) has become a major focus of research in recent years, attracting attention from both academia and industry. Numerous studies have explored IoT architectures, communication protocols, security frameworks, and applications across diverse domains. This section reviews existing literature to provide an overview of the current state of research, highlight limitations, and identify research gaps that motivate the present study.



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Application Domains of IOT

IoT applications are diverse and span across many different sectors. Key areas include smart homes, smart cities, healthcare, industrial automation, and agriculture, among others. These applications leverage interconnected devices to automate tasks, improve efficiency, and enhance safety and convenience. IoT has found applications across multiple domains:

- **Healthcare:** Wearable devices and remote monitoring have been studied for early disease detection and patient care (Islam *et al.*, 2015). Security and reliability remain major concerns in this domain.
- **Smart Homes and Cities:** Research has focused on energy management, surveillance, and intelligent resource utilization (Al Nuaimi *et al.*, 2015). However, issues of data integration across diverse devices limit large-scale adoption.
- **Industrial IoT (IIoT):** Studies highlight predictive maintenance, real-time monitoring, and automation in manufacturing (Zhou *et al.*, 2015). The primary challenge lies in ensuring low latency and high reliability.
- **Agriculture:** Precision farming using IoT has shown promise in water management, soil monitoring, and yield optimization (Wolfert *et al.*, 2017). Connectivity in rural areas remains a barrier.
- **Cloud Computing:** Provides scalable storage and processing power but suffers from latency issues.
- **Fog and Edge Computing:** Reduce latency and improve scalability by processing data near devices.
- **Artificial Intelligence (AI) and Machine Learning (ML):** Enhance predictive analytics, anomaly detection, and smart automation.
- **Blockchain:** Provides decentralized trust, secure transactions, and tamper-proof data sharing in IoT networks.
- **5G/6G Communication:** Enable ultra-reliable, high-speed, and low-latency IoT connectivity for next-generation applications.

Challenges in IOT

1. Despite the rapid growth and adoption of IoT across various sectors, several challenges continue to limit its scalability, reliability, and security. The foremost issue is **security and**



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- privacy**, since most IoT devices are resource-constrained and lack robust protection mechanisms, making them vulnerable to attacks such as malware, denial-of-service, and unauthorized access.
2. Even when devices support similar functionalities, variations in data formats, communication interfaces, and operating systems often prevent smooth coordination. This is particularly problematic in large-scale deployments like smart cities and industrial IoT, where multiple vendors' systems must work together efficiently. Additionally, **energy constraints** remain a major barrier, as many IoT devices rely on battery power and frequent data transmission accelerates energy depletion, thereby affecting long-term sustainability.
 3. IoT requires lightweight protocols suitable for constrained devices. MQTT and CoAP have been widely studied for efficient communication in low-power networks (Al-Fuqaha *et al.*, 2015). Research comparing them found that MQTT ensures reliable delivery while CoAP is more efficient in constrained networks.
 4. LPWAN technologies such as **LoRaWAN**, **Sigfox**, and **NB-IoT** have been proposed for long-range, low-energy communication, making them suitable for agriculture and environmental monitoring (Raza *et al.*, 2017). 5G networks and upcoming **6G technologies** are also being explored for ultra-reliable low-latency IoT applications, such as autonomous vehicles and industrial automation. Despite these advances, interoperability between protocols remains a significant barrier.

Research Methodology

Research methodology provides the systematic framework through which the study is conducted. It outlines the approach, tools, techniques, and strategies used to investigate the research problem and achieve the stated objectives.

Since this research focuses on reviewing existing IoT architectures, analyzing challenges, and proposing an enhanced edge/fog-integrated IoT framework, a **qualitative and analytical research methodology** is adopted.

The methodology combines **secondary research (literature review, surveys of prior work, comparative analysis of architectures and protocols)** with **conceptual modeling**



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(proposal of enhanced IoT architecture). This ensures a comprehensive understanding of the current landscape while enabling the identification of gaps and formulation of effective solutions.

Data Collection Methods

The study relies on **secondary data collection methods**, as IoT research is well-documented in academic, industrial, and government publications. The sources include:

- **Academic Databases:** IEEE Xplore, Springer, Elsevier (ScienceDirect), ACM Digital Library, ResearchGate, MDPI, and arXiv.
- **Standards & Guidelines:** Publications from ITU (International Telecommunication Union), IETF (Internet Engineering Task Force), ISO, and IEEE.
- **Industrial Reports:** White papers, technical reports, and case studies from leading IoT organizations and technology companies.
- **Books and Review Articles:** To provide foundational and conceptual understanding of IoT systems and technologies.

Only peer-reviewed, authentic, and up-to-date sources (2010 onwards, with emphasis on 2015–2025) are considered to ensure reliability.

Conclusion

The Internet of Things (IoT) represents a transformative technological paradigm that bridges the physical and digital worlds through pervasive connectivity, intelligent sensing, and real-time data processing. This study has explored IoT from multiple perspectives, including its **architectural models, enabling technologies, communication protocols, application domains, and key challenges**. The review of literature revealed that while IoT has achieved remarkable growth across diverse sectors such as smart homes, healthcare, transportation, agriculture, and industry, several limitations continue to hinder its large-scale deployment. In conclusion, IoT holds immense potential to revolutionize industries, improve human life, and enable smarter, data-driven decision-making. However, its future success depends on addressing the critical challenges of **security, scalability, energy efficiency, and standardization**. The integration of



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edge/fog computing, coupled with advances in artificial intelligence, blockchain, and next-generation communication technologies (5G/6G), is expected to shape the next phase of IoT evolution.

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Full Length Article

IJCRAR/FL/07

Data Science for Disaster Management & Disaster Management Systems

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Abstract

Natural disasters such as floods, earthquakes, cyclones, and wildfires cause massive loss of life and property worldwide. Traditional disaster management systems often rely on manual reporting and reactive strategies, which are insufficient in mitigating large-scale damage. With the growth of big data, machine learning, IoT, and remote sensing technologies, data science offers transformative potential in disaster prediction, preparedness, and response. This paper explores how data-driven approaches can enhance disaster management by integrating multi-source data (satellite imagery, social media, IoT sensors, and historical records) to build predictive and early warning systems. It also discusses methodologies, real-world applications, challenges, and future directions in this domain.

Keywords: Data Science, Disaster Management, Early Warning Systems, Machine Learning, IoT, Remote Sensing

Introduction

Natural disasters such as floods, earthquakes, cyclones, landslides, droughts, and wildfires have become increasingly frequent and severe in recent decades. According to the United Nations Office for Disaster Risk Reduction (UNDRR), the number of disaster events has almost doubled over the past two decades, largely due to the impacts of climate change, unplanned urbanization, and environmental degradation. These disasters not only cause tragic



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loss of human lives but also lead to long-term socio-economic consequences, including displacement of communities, large-scale infrastructure damage, agricultural losses, and economic instability across regions.

Traditional disaster management strategies have primarily relied on manual reporting, historical trend analysis, and human-driven monitoring. While these methods have provided valuable insights in the past, they are often slow, fragmented, and reactive in nature. In many cases, by the time warnings are issued, the crucial window for effective response has already closed, resulting in massive casualties and economic setbacks. This gap highlights the urgent need for data-driven, predictive, and proactive frameworks that can provide timely and accurate early warnings to minimize both human and material losses.

Main objective

1. To highlight the role of data science in disaster prediction, detection, and response, showcasing how advanced analytics can transform traditional disaster management practices.
2. To explore data-driven methodologies and technologies such as machine learning, deep learning, IoT, remote sensing, and big data platforms in building efficient disaster management and early warning systems.
3. To examine real-world applications and case studies where data science has been successfully applied to predict, monitor, and mitigate the impact of natural disasters.

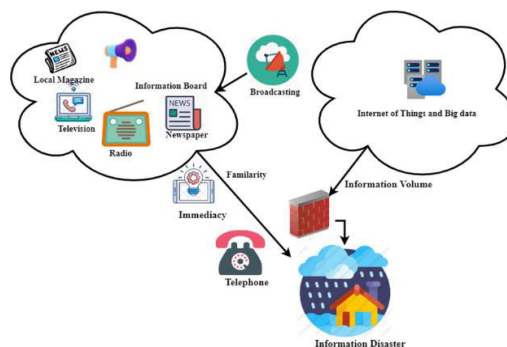


Fig 7.1



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Review of literature

Flood Forecasting and Inundation Mapping

Flood prediction has advanced from local hydrological models to **globally scalable AI systems**. Google's framework in India and Bangladesh combined ML-based stage forecasting with high-resolution inundation mapping, improving warning lead times for millions. Recent studies extend this to **global river forecasting** with up to seven-day lead times, showing applicability even in data-scarce regions. Complementing these models, the **Global Flood Monitoring System (GFMS)** uses satellite

Remote Sensing for Rapid Damage and Hazard Mapping

Remote sensing plays a vital role in rapid disaster assessment. **Synthetic Aperture Radar (SAR)** from Sentinel-1 enables reliable flood mapping under all weather conditions, with deep learning models like CNNs and U-Net showing strong performance. However, misclassification over water-like surfaces highlights the need for **multi-sensor fusion** with Sentinel-2 optical data.

Earthquake Early Warning (EEW) and Seismic Analytics

Seismic data analytics has facilitated the development of Earthquake Early Warning (EEW) systems that provide critical seconds to minutes of lead time. Such systems detect fast-propagating P-waves and estimate the arrival and intensity of destructive S-waves. Comparative literature highlights similar operational EEW systems in Japan, Mexico, Italy, and Taiwan, each adapted to regional tectonic conditions, sensor networks, and communication infrastructure.

Social Media and NLP for Situational Awareness

Social media has become an invaluable supplementary data source during crises, providing real-time, crowd-sourced information. Research demonstrates that **Natural Language Processing (NLP)** techniques can accelerate needs assessment, damage mapping, rumor detection, and volunteer coordination.



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Food Security and Drought Early Warning

Beyond hydro-meteorological events, data science has also been applied to food security monitoring. The **Famine Early Warning Systems Network (FEWS NET)** exemplifies a multidisciplinary, data-driven approach that integrates remote sensing (rainfall, NDVI), market data, and livelihood indicators to generate scenario-based food security outlooks.

Research methodology

The methodology adopted in this study follows a systematic approach to reviewing, analyzing, and synthesizing existing frameworks, models, and applications of data science in disaster management. The methodology is divided into the following stages:

1. Research Design

A qualitative, exploratory research design was chosen, focusing on secondary data from peer-reviewed journals, government reports, and international organizations (e.g., UNDRR, USGS, NASA). The design emphasizes identifying how data science techniques are being applied in disaster prediction, preparedness, and response.

2. Data Collection

- **Sources:** Academic databases (ScienceDirect, IEEE Xplore, Springer, Taylor & Francis), organizational reports (UNDRR, World Bank, USGS), and operational platforms (NASA FIRMS, Google Flood Forecasting, GFMS).
- **Selection Criteria:** Literature published between 2015–2025, prioritizing works related to AI, machine learning, big data, remote sensing, GIS, and IoT in disaster contexts.

3. Analytical Framework

- **Content Analysis:** Categorizing studies based on disaster type, technology used (ML, remote sensing, NLP, IoT), and outcomes (prediction accuracy, lead time improvement, situational awareness).



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- **Comparative Analysis:** Evaluating the strengths, limitations, and transferability of existing models across regions and hazard types.
- **Thematic Mapping:** Identifying cross-cutting themes such as uncertainty quantification, explainability, and last-mile communication challenges.

4. Validation Approach

To ensure credibility, findings from case studies (e.g., Google Flood Forecasting, ShakeAlert, NASA FIRMS) were cross-referenced with independent reports and humanitarian response outcomes. This triangulation approach validates the real-world impact of data-driven systems.

5. Outcome of Methodology

The methodology enabled the identification of current trends, success stories, technological gaps, and future research directions for developing robust, inclusive, and predictive disaster management systems powered by data science.

Conclusion

Data science offers an unprecedented opportunity to shift disaster management from a reactive paradigm to a proactive, predictive, and real-time framework. By leveraging multi-source datasets—such as remote sensing imagery, IOT sensor feeds, hydrological and meteorological records, and social media streams—combined with advanced Machine Learning (ML) and Deep Learning (DL) models, societies can significantly improve forecasting accuracy, optimize early warning systems, and strengthen crisis decision-making. This transformation has the potential to reduce human casualties, minimize economic losses, and enhance community resilience in disaster-prone regions.

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Full Length Article

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Artificial Intelligence in Healthcare: A Transformative Force for the Future

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Abstract

Artificial Intelligence (AI) is reshaping the healthcare industry by enhancing diagnostic accuracy, improving patient outcomes, and increasing operational efficiency. From medical imaging to predictive analytics, AI applications are expanding rapidly across various domains. This paper explores the evolving role of AI in healthcare, reviewing current literature, analyzing methodologies in research and deployment, and addressing implementation challenges. Despite significant advancements, concerns around data privacy, algorithmic bias, and lack of transparency persist. This study provides a balanced perspective on how AI is transforming healthcare, along with its limitations and future implications for clinical practice, policy, and research.

Keywords: Artificial Intelligence (AI), machine learning, natural language processing (NLP)

Introduction

The global healthcare system is under increasing pressure due to aging populations, rising costs, and limited access to medical professionals in many regions. In response, Artificial Intelligence (AI) is being embraced as a tool with the potential to revolutionize healthcare delivery and administration. AI in healthcare encompasses a broad spectrum of technologies, including machine learning, natural language processing (NLP), computer vision, and robotic systems. These technologies are being used to support clinical decision-making, automate routine tasks, and predict health outcomes.



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Healthcare providers and researchers are turning to AI to tackle long-standing inefficiencies. For example, AI-powered diagnostic tools can process vast amounts of patient data and imaging scans more rapidly and accurately than human clinicians in some cases. In hospitals, AI is used to manage electronic health records (EHRs), schedule appointments, and predict patient readmissions. Moreover, AI supports drug discovery, telemedicine, and remote monitoring – areas particularly vital in underserved communities.

However, as promising as AI appears, it raises several ethical and technical concerns. These include the risk of bias in training data, lack of explainability in decision-making algorithms, cybersecurity vulnerabilities, and the uncertain legal and regulatory environment. Thus, while AI offers immense opportunities, careful implementation and oversight are essential.

Literature Review

AI in Diagnostics

One of the most extensively studied applications of AI is in diagnostic imaging. Deep learning models, especially convolutional neural networks (CNNs), have been successfully trained to detect diseases from radiological images. Esteva *et al.*, (2017) developed a model that diagnosed melanoma with accuracy comparable to board-certified dermatologists. Similarly, AI has been applied to mammography, lung scans, and retinal imaging to detect cancer, pneumonia, and diabetic retinopathy.

AI also supports pathology by analyzing biopsy images to detect microscopic changes that could indicate cancer or other diseases. These models reduce the burden on pathologists and improve consistency in diagnosis. Notably, studies have shown that AI-assisted diagnosis can reduce false positives and false negatives, especially when used in conjunction with human expertise.

Predictive Analytics

AI models can identify patterns in large datasets, enabling predictive analytics for patient care. For instance, Obermeyer *et al.*, (2016) demonstrated how machine learning algorithms



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could predict which patients were likely to require intensive care. Similarly, AI tools have been developed to forecast hospital readmissions, disease progression, and patient deterioration in real-time, especially in intensive care units (ICUs).

Predictive models are also used in public health to track and forecast infectious disease outbreaks. During the COVID-19 pandemic, AI was utilized to monitor the spread of the virus and evaluate the impact of public health interventions.

Ethical and Legal Considerations

AI in healthcare raises significant ethical questions. One primary concern is **bias** in training data, which can lead to unequal treatment outcomes for different demographic groups. Another concern is **transparency**: many AI models are “black boxes” with decision-making processes that are not easily interpretable by humans. Additionally, the use of patient data for training AI models presents risks to **privacy** and **data security**. Topol (2019) emphasizes the need for human-centered AI, suggesting that ethical guidelines and regulatory oversight must evolve alongside technology.

Materials and Methods

This paper uses a **narrative literature review** approach combined with qualitative thematic analysis.

Data Sources

Research articles were retrieved from academic databases such as PubMed, ScienceDirect, IEEE Xplore, and Google Scholar. Keywords included “AI in healthcare,” “machine learning in medicine,” “healthcare automation,” and “clinical decision support systems.”

Selection Criteria

- Peer-reviewed articles published between 2015 and 2025
- Focus on real-world applications of AI in healthcare



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- Inclusion of both clinical and administrative use cases
- Articles addressing ethical and regulatory issues

Analysis Process

Selected articles were categorized by:

- AI application domain (diagnosis, predictive analytics, administration)
- Type of AI technology used (machine learning, NLP, robotics)
- Reported outcomes (accuracy, efficiency, impact on healthcare delivery)

Insights were synthesized to identify emerging trends, best practices, and common challenges.

Limitations

While this research provides a comprehensive overview, several limitations exist:

1. **Scope and Language:** Only English-language studies were reviewed, potentially omitting significant research from non-English-speaking countries.
2. **Rapid Technological Change:** AI evolves quickly, and studies from even a few years ago may be outdated or superseded by newer technologies.
3. **Lack of Standardization:** There is a lack of standardized benchmarks across studies, making direct comparison of results difficult.
4. **Geographic Bias:** Most literature focuses on high-income countries, while AI adoption and impact in low- and middle-income countries remain underexplored.
5. **No Quantitative Analysis:** This review is qualitative and does not include statistical meta-analysis to validate AI effectiveness across multiple studies.

Conclusion

Artificial Intelligence has the potential to dramatically improve healthcare by supporting clinical decision-making, enhancing diagnostic precision, predicting patient risks, and



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streamlining administrative functions. Its applications are wide-ranging, from interpreting medical images to forecasting disease outbreaks and automating hospital operations.

However, AI's success in healthcare depends on addressing key challenges: data bias, ethical use of patient information, algorithm transparency, and the development of robust regulatory frameworks. To ensure equitable and responsible implementation, AI systems must be developed with inclusivity, accountability, and human oversight in mind.

Moving forward, collaborative efforts among healthcare professionals, technologists, policymakers, and ethicists are crucial. By aligning AI development with clinical needs and ethical standards, we can harness its full potential to create a more efficient, accessible, and patient-centered healthcare system.

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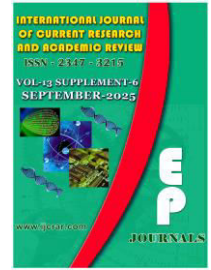


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Full Length Article

IJCRAR/FL/09

An Analytical Study of Data Mining Techniques in Data Science

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Abstract

This paper provides an analytical study of key data mining techniques widely used in data science to discover valuable insights from large and complex datasets. Techniques such as classification, clustering, association rule mining, and regression are examined to understand their roles, advantages, and limitations. The study analyzes how these methods contribute to extracting meaningful patterns, improving decision-making, and solving real-world problems in various domains like healthcare, finance, and marketing. Through this analysis, the paper aims to offer a clear understanding of the effectiveness and challenges of data mining techniques, helping researchers and practitioners apply them more efficiently in data science projects.

Keywords: social media, sensors, business transactions, patterns, trends

Introduction

In today's world, data is generated at an unprecedented rate from various sources like social media, sensors, and business transactions. Data science is the field that focuses on extracting useful information from this vast amount of data to support better decision-making. One of the most important parts of data science is data mining, which involves using different techniques to find patterns, trends, and relationships within large datasets. These patterns can help organizations understand their data better and make predictions about future events. This paper analyzes some of the most commonly used data mining techniques, including



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classification, clustering, and association rule mining. It explores how these techniques work, their strengths and weaknesses, and how they are applied in real-world scenarios. The goal is to provide a clear understanding of data mining's role in data science and its impact on various industries.

Materials and Methods

This study analyzes various data mining techniques by reviewing existing research papers, case studies, and real-world applications in data science. The focus is on understanding how methods like classification, clustering, association rule mining, and regression are implemented to solve different problems. Each technique is examined in terms of its process, advantages, and limitations. Additionally, the paper compares the effectiveness of these techniques across industries such as healthcare, finance, and marketing. By synthesizing information from multiple sources, this analysis aims to provide a comprehensive overview of data mining techniques and their practical value in data science.

Literature Review

Data mining has been widely studied and applied in the field of data science for many years. Early research focused on developing core techniques such as classification, clustering, and association rule mining to handle large datasets effectively. For example, classification algorithms like decision trees and support vector machines have been used extensively for predictive analysis. Clustering techniques, such as k-means, help group similar data points, which is useful in customer segmentation and image analysis. Association rule mining uncovers relationships between variables, commonly applied in market basket analysis.

Recent studies have explored improvements in these techniques through machine learning and artificial intelligence to increase accuracy and efficiency. Many researchers highlight the importance of selecting the right data mining method based on the nature of the dataset and the problem being solved. Applications across various industries, including healthcare for disease prediction, finance for fraud detection, and marketing for customer behavior analysis, demonstrate the versatility of data mining. However, challenges such as data quality, scalability, and privacy concerns remain important issues addressed in the literature.



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Data Mining Algorithms

Data mining relies on various algorithms to extract patterns and insights from large datasets. Some of the most common algorithms include:

1. **Classification Algorithms:** These algorithms categorize data into predefined classes. Examples include Decision Trees, Naive Bayes, and Support Vector Machines (SVM). They are often used for tasks like spam detection and medical diagnosis.
2. **Clustering Algorithms:** These group similar data points without predefined labels. Popular clustering algorithms include K-Means, Hierarchical Clustering, and DBSCAN. Clustering helps in customer segmentation, image analysis, and pattern recognition.
3. **Association Rule Mining:** This algorithm discovers interesting relationships between variables in large databases. The Apriori algorithm is a classic example, commonly used in market basket analysis to find products frequently bought together.
4. **Regression Algorithms:** These predict continuous values based on input variables. Linear regression and logistic regression are widely used for forecasting and risk assessment.

Each algorithm has its strengths and is chosen based on the data type and the problem's requirements. Understanding these algorithms helps data scientists select the right approach for effective data mining.

Tools Used

1. Weka

- **Type:** Open-source
- **Use:** Weka is widely used for academic studies and practical applications in data mining due to its simplicity and comprehensive suite of algorithms.
- **Features:** It provides a wide range of tools for data pre-processing, classification, clustering, regression, and association rule mining. Weka also includes visualizations that help users interpret data patterns effectively.
- **Link:** Weka Official Site



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2. RapidMiner

- **Type:** Free & Commercial Versions
- **Use:** RapidMiner is extensively used in both academic and industry settings, known for its user-friendly, drag-and-drop interface, making it easy for both beginners and professionals.
- **Features:** It supports data preprocessing, machine learning, deep learning, and model deployment, offering a versatile environment for various data mining tasks.
- **Link:** RapidMiner Official Site

Conclusion

Data mining is a vital component of data science that enables the extraction of meaningful patterns and insights from large and complex datasets. This analytical study reviewed key data mining techniques such as classification, clustering, association rule mining, and regression, highlighting their applications, strengths, and limitations. The paper showed how these techniques are widely used across various industries to improve decision-making, predict trends, and solve real-world problems. Despite challenges like data quality and privacy concerns, data mining continues to evolve with advances in machine learning and artificial intelligence. In addition, the integration of data visualization tools with data mining techniques enhances the interpretability of results, allowing users to better understand and communicate complex findings. Moreover, the success of data mining largely depends on skilled professionals who can choose appropriate methods, handle data ethically, and draw accurate conclusions. Understanding and effectively applying these techniques is essential for leveraging the full potential of data science in today's data-driven world.

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Full Length Article

IJCRAR/FL/10

IOT-Based Home Security System

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Abstract

The Internet of Things (IoT) has transformed traditional home security by enabling interconnected devices to provide real-time monitoring, alerts, and control over home environments remotely. An IoT-based home security system integrates sensors, cameras, and smart locks into a unified platform accessible via the internet, allowing homeowners to detect intrusions, fire hazards, or other threats instantly. This system enhances safety, convenience, and responsiveness through automation and remote accessibility. This paper discusses the design, applications, benefits, limitations, and future potential of IoT-enabled home security solutions.

Keywords: motion detectors, surveillance cameras, smoke sensors, smart locks

Introduction

Home security has long been a priority for homeowners seeking to protect their property and loved ones. With advancements in technology, the Internet of Things (IoT) has introduced innovative ways to enhance home security systems beyond traditional alarms. IoT-based home security systems use interconnected devices such as motion detectors, surveillance cameras, smoke sensors, and smart locks that communicate via wireless networks to provide continuous monitoring and instant alerts.

These smart systems allow users to remotely monitor their homes using smartphones or web applications, control security devices, and automate responses to threats. The integration of



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IOT not only improves security effectiveness but also offers convenience and peace of mind, making it increasingly popular in modern households.

Materials and Methods

The methodology for developing an IoT-based home security system involves designing and integrating various hardware and software components to ensure real-time monitoring and control. Initially, sensor modules such as motion detectors, cameras, and gas sensors are installed to detect unauthorized access or environmental hazards. These sensors are connected to a microcontroller or microprocessor, like an Arduino or Raspberry Pi, which processes the collected data. The system uses wireless communication protocols such as Wi-Fi or Zigbee to transmit information to a cloud server or directly to a user's smartphone application.

The software component is programmed to analyze sensor inputs, trigger alerts, and activate actuators like alarms or door locks in case of suspicious activity. The system interface allows users to remotely monitor their homes, receive notifications, and control security devices in real-time. Testing and calibration are conducted under various scenarios to evaluate response time, accuracy, and overall reliability, ensuring the system is robust and user-friendly.

Literature Review

IoT-based home security systems are increasingly studied for their ability to provide real-time monitoring using sensors like motion detectors and cameras paired with microcontrollers such as Arduino and Raspberry Pi. Wireless technologies like Wi-Fi and Zigbee facilitate communication between devices and user interfaces. Despite their benefits, these systems face significant security risks, including cyber-attacks and privacy concerns.

To address this, researchers have explored machine learning-based intrusion detection systems to detect unusual activities. Cloud integration and mobile apps enhance remote control and monitoring. Strong encryption and authentication are crucial for protecting data. Overall, the literature highlights the need for combining hardware innovation, software intelligence, and cybersecurity to create effective and secure home security solutions.



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Applications

- **Intrusion Detection:** Detects unauthorized entry through door/window sensors and motion detectors, triggering alarms and notifications.
- **Real-Time Video Surveillance:** Allows remote viewing and recording of home environments through IP cameras accessible via smartphones.
- **Fire and Smoke Detection:** Monitors smoke and fire hazards, sending immediate alerts to homeowners and emergency services.
- **Remote Access Control:** Smart locks enable locking/unlocking doors remotely, enhancing access management.
- **Environmental Monitoring:** Detects gas leaks, water leaks, or unusual temperature variations.
- **Automated Alert Systems:** Sends instant SMS, email, or push notifications on detecting security breaches or hazards.

Advantages

- **Remote Accessibility:** Monitor and control home security systems from anywhere via internet-connected devices.
- **Real-Time Alerts:** Immediate notifications enable quick action to prevent or mitigate damage.
- **Enhanced Safety:** Continuous monitoring reduces risks of theft, fire, and other emergencies.
- **User-Friendly Interfaces:** Mobile apps and dashboards provide easy management and monitoring.
- **Cost Efficiency:** Lowers reliance on security personnel and expensive infrastructure.

Disadvantages

- **Internet Dependency:** System performance can degrade or fail during network outages.
- **Privacy and Security Risks:** Data breaches or unauthorized access can compromise sensitive information and live feeds.
- **Technical Complexity:** Installation, configuration, and maintenance may be challenging for non-experts.



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- **Vulnerability to Cyber Attacks:** IoT devices can be exploited if not regularly updated or secured.
- **Cost of Updates:** Regular updates and adding new features might incur additional expenses.

Conclusion

IoT-based home security systems represent a significant advancement in protecting homes by combining connectivity, automation, and real-time monitoring. They offer greater control, convenience, and responsiveness compared to traditional security methods. However, challenges such as privacy concerns, dependence on internet connectivity, and potential cyber vulnerabilities must be addressed through robust security practices and user awareness. With ongoing technological improvements and increased adoption, IoT-based security solutions are poised to become standard in modern homes, providing safer and smarter living environments.

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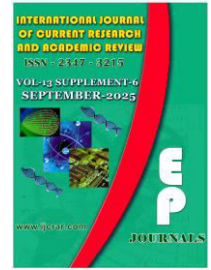


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Full Length Article

IJCRAR/FL/11

Re Inforce AI

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Abstract

Reinforcement Learning (RL) is a rapidly growing area of Artificial Intelligence that focuses on training agents to make sequential decisions through interaction with their environment. Unlike supervised learning, RL learns from feedback in the form of rewards or penalties, enabling systems to optimize long-term performance. This paradigm has shown remarkable success in fields such as robotics, autonomous systems, natural language processing, and game playing. By combining deep learning with RL techniques, modern AI systems can handle complex, high-dimensional environments and adapt dynamically to changing conditions. Reinforce AI thus represents a critical step toward building intelligent, self-learning, and adaptive decision-making systems.

Keywords: Reinforcement Learning (RL), Artificial Intelligence, optimal strategies

Introduction

Reinforcement Learning (RL) is an advanced paradigm of Artificial Intelligence that focuses on enabling autonomous agents to learn optimal strategies through continuous interaction with their environment. Unlike supervised and unsupervised learning approaches, RL does not depend on labeled datasets but instead uses a system of rewards and penalties to guide the learning process. The agent observes the state of the environment, performs actions, and receives feedback in the form of cumulative rewards, thereby gradually improving its decision-making ability. One of the most widely studied policy gradient methods is the **REINFORCE algorithm**, which updates the policy parameters in the direction of higher rewards using gradient ascent. This technique has shown remarkable results in solving sequential



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decision-making problems, particularly in high-dimensional and dynamic environments. Applications of Reinforce AI span across diverse domains such as robotics, autonomous driving, industrial automation, healthcare optimization, and game-playing systems like AlphaGo. However, despite its effectiveness, RL techniques often suffer from challenges such as **sample inefficiency, slow convergence, instability in training, and safety concerns in real-world deployment**. Addressing these challenges is essential for advancing Reinforce AI toward building scalable, reliable, and adaptive intelligent systems..

Literature Review

Reinforcement Learning (RL) has evolved significantly over the past decades, beginning with foundational works such as Sutton and Barto's framework (1998), which formalized the concepts of agents, environments, and reward-driven learning. Early methods like Q-learning and policy gradient approaches laid the groundwork for adaptive decision-making systems. With the rise of Deep Learning, Deep Reinforcement Learning (Mnih *et al.*, 2015) demonstrated human-level performance in complex environments like Atari games, highlighting the potential of combining neural networks with RL. Subsequent studies extended RL applications to robotics (Kober *et al.*, 2013), autonomous driving (Kendall *et al.*, 2019), and healthcare (Yu *et al.*, 2021), proving its versatility in real-world problem solving. Recent advancements also explore safe RL, multi-agent RL, and explainability to overcome challenges of scalability, interpretability, and ethical use.

Materials and Methods

The methodology of Reinforce AI is based on modeling decision-making problems as a **Markov Decision Process (MDP)**, where an agent interacts with an environment characterized by states, actions, rewards, and state transitions. The agent's objective is to learn an optimal policy that maximizes long-term cumulative rewards. At each time step, the agent observes the current state, selects an action according to its policy, and receives feedback from the environment in the form of rewards and next states. Policies are often parameterized using neural networks, enabling the handling of high-dimensional and complex environments. Learning occurs iteratively, with policy parameters updated to favor actions that result in higher rewards. This methodology allows agents to adapt dynamically to changes in the environment,



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making it particularly effective for applications such as robotics, autonomous systems, and gaming, where the system must continuously improve its decision-making through interaction.

Algorithm

A central algorithm in Reinforce AI is the **REINFORCE algorithm**, a type of policy gradient method that directly optimizes the agent's policy based on expected cumulative rewards. The process begins by initializing the policy parameters, after which the agent generates trajectories by interacting with the environment according to its current policy. For each trajectory, the cumulative return G_t is calculated, representing the sum of discounted rewards from each time step. The policy is then updated using the formula:

1.
$$\theta = \theta + \alpha \sum_t \nabla_{\theta} \log \pi_{\theta}(a_t | s_t) (G_t - \bar{G})$$
2. Here, θ denotes the policy parameters, α is the learning rate, $\pi_{\theta}(a_t | s_t)$ is the probability of taking action a_t in state s_t , and G_t is the return. This update reinforces actions that yield higher rewards, gradually improving the policy. While REINFORCE is conceptually simple and effective, it can suffer from high variance in updates and slow convergence. To address these limitations, more advanced algorithms such as Actor-Critic, Proximal Policy Optimization (PPO), and Deep Q-Networks (DQN) have been developed, offering improved stability, efficiency, and scalability for complex environments.

Conclusion

Reinforce AI, built upon reinforcement learning principles, provides a robust framework for developing agents capable of adaptive and intelligent decision-making through trial-and-error interactions. Its applications span diverse fields including robotics, autonomous vehicles, gaming, healthcare, and industrial automation, demonstrating significant improvements in performance and efficiency. Despite these successes, challenges such as **sample inefficiency, slow convergence, high computational demands, safety risks, and limited generalization** continue to restrict widespread real-world deployment. Future research aims to enhance efficiency, stability, and safety through hybrid methods, multi-agent reinforcement learning,



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and policy optimization strategies, making Reinforce AI increasingly practical and reliable for solving complex, real-world problems.

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Full Length Article

IJCRAR/FL/12

Application of Pattern Recognition in Artificial Intelligent and Machine Learning

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Abstract

The application of pattern recognition in Artificial Intelligence (AI) and Machine Learning (ML) has led to significant advancements across a wide range of industries. By enabling machines to identify and learn from patterns in data, AI systems can perform complex tasks such as facial recognition, speech interpretation, and predictive analytics with high accuracy. This paper focuses on practical implementations of pattern recognition, highlighting its impact in healthcare (disease detection), finance (fraud prevention), and transportation (autonomous vehicles). Various models and techniques, including convolutional neural networks (CNNs) and clustering methods, are reviewed to illustrate how they contribute to real-world problem-solving. The abstract concludes by examining the future potential of pattern recognition as AI technologies continue to evolve.

Keywords: Artificial Intelligence (AI), Machine Learning (ML), input data, pattern recognition

Introduction

Pattern recognition is a fundamental aspect of Artificial Intelligence (AI) and Machine Learning (ML), enabling systems to automatically detect, classify, and analyze patterns within data. It involves the identification of regularities and structures in input data, which helps machines make informed decisions without explicit programming. In recent years, pattern recognition has become increasingly important due to the rapid growth of data and the need for intelligent systems that can process and interpret this data effectively.



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With advancements in algorithms and computational power, pattern recognition techniques are now widely applied in various fields such as image and speech recognition, natural language processing, medical diagnostics, and financial forecasting. Machine learning models, especially deep learning architectures like Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), have significantly improved the accuracy and efficiency of pattern recognition tasks. Another crucial benefit of pattern recognition is its ability to handle unstructured data—such as images, audio, and text—which makes it a key technology in building intelligent human-computer interfaces, like virtual assistants and real-time language translators.

Pattern recognition has been a significant area of research within Artificial Intelligence (AI) and Machine Learning (ML) for several decades. Various studies and research papers have highlighted its importance, development, and practical implementation across multiple domains.

Foundational Research

Early research in pattern recognition focused on statistical approaches and rule-based systems. Duda and Hart (1973) laid the groundwork with their book *Pattern Classification and Scene Analysis*, which emphasized statistical decision theory as a key method. These classical methods, such as **Bayesian classifiers** and **linear discriminant analysis (LDA)**, formed the basis for more complex models developed in later years.

Machine Learning-Based Approaches

With the evolution of ML, researchers began using supervised and unsupervised learning methods for pattern recognition. Support Vector Machines (SVM), Decision Trees, k-Nearest Neighbors (k-NN), and Naive Bayes classifiers gained popularity for classification tasks due to their simplicity and effectiveness (Cortes & Vapnik, 1995). In unsupervised learning, clustering algorithms like k-means and DBSCAN have been widely used for recognizing hidden patterns in unlabeled datasets.

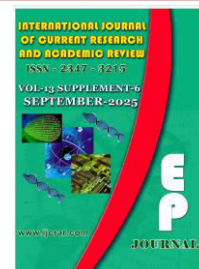


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Rise of Deep Learning

In recent years, deep learning has transformed the field of pattern recognition. Convolutional Neural Networks (CNNs), as proposed by LeCun *et al.*, have become essential for image and video recognition. Similarly, Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks have been widely used for sequential data like speech and text. These deep models have significantly outperformed traditional ML models in terms of accuracy and feature extraction capabilities.

Applications Across Domains

Several studies demonstrate the application of pattern recognition in diverse sectors. In healthcare, pattern recognition helps in early disease detection through analysis of X-rays, MRIs, and ECG data (Esteva *et al.*, 2017). In finance, pattern recognition models are used to detect anomalies in transaction data to prevent fraud. Natural Language Processing (NLP) uses these techniques to power machine translation, sentiment analysis, and chatbots. In biometrics, facial recognition and fingerprint analysis are major implementations of pattern recognition.

Current Trends and Challenges

Recent literature also focuses on making pattern recognition models more **interpretable, ethical, and generalizable**. There's growing attention to the **bias** and **fairness** of AI systems, especially when trained on imbalanced datasets. Additionally, researchers are exploring **transfer learning** and **few-shot learning** to improve model performance when limited data is available.

Materials and Methods

1. **Data Collection:** Gather relevant datasets from open-source repositories (e.g., image datasets for facial recognition, medical datasets for diagnosis, etc.).
2. **Data Preprocessing:** Clean and normalize the data, handle missing values, and perform feature extraction or dimensionality reduction as needed.
3. **Model Selection:** Choose suitable algorithms based on the type of data:
 - o **Traditional ML:** SVM, k-NN, Decision Trees for smaller datasets.



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- **Deep Learning:** CNNs for image data, RNNs/LSTMs for sequence data.
- 4. **Training and Validation:** Split data into training and testing sets. Train the model using supervised or unsupervised learning techniques.
- 5. **Performance Evaluation:** Evaluate the model using metrics like accuracy, precision, recall, F1-score, and confusion matrix.
- 6. **Deployment (Optional):** For applicable projects, deploy the model in a real-time or simulated environment to demonstrate its practical use.

Challenges

1. **Data Quality and Noise:** Pattern recognition systems are highly sensitive to noisy, incomplete, or irrelevant data, which can affect accuracy.
2. **High Dimensionality:** Processing large and complex datasets, especially images and audio, requires significant computational power and optimized models.
3. **Overfitting:** Models may perform well on training data but fail to generalize to unseen data.
4. **Interpretability:** Deep learning models often act as black boxes, making it difficult to understand their decision-making process.
5. **Bias and Fairness:** If training data is biased, the model may produce unfair or discriminatory outcomes.
6. **Real-Time Processing:** Many applications require real-time pattern recognition, which demands efficient algorithms and fast processing.
7. **Security and Privacy:** In applications like facial recognition, ensuring user privacy and protecting sensitive data is a major concern.

Conclusion

Pattern recognition is a powerful tool that enables AI and ML systems to make intelligent decisions by learning from data. Its applications span across numerous fields such as healthcare, finance, security, and automation. With the emergence of deep learning, the capability and accuracy of pattern recognition systems have significantly improved. However, challenges such as data quality, model interpretability, and ethical concerns still remain. Addressing these issues is crucial for the responsible and effective deployment of pattern recognition technologies.



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Continued research and innovation will play a key role in making these systems more robust, transparent, and widely accessible.

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Full Length Article

IJCRAR/FL/13

Face Recognition With and Without Masks Using Machine Learning (HAAR CASCADE and LBPH)

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Abstract

Face recognition systems are widely used in security, surveillance, and attendance applications. However, the widespread use of face masks after the COVID-19 pandemic has created new challenges for traditional recognition methods, which rely on full-face visibility. This project presents a face recognition system capable of identifying individuals with and without face masks. The system uses OpenCV for face detection through Haar Cascade classifiers and performs recognition using the Local Binary Patterns Histogram (LBPH) algorithm. The LBPH method is simple, fast, and effective for real-time applications. The system is trained using a dataset containing both masked and unmasked images, improving its ability to recognize partially covered faces. The project demonstrates that even classical computer vision techniques can provide reliable performance in modern-day conditions involving partial facial occlusion.

Keywords: banks, offices, airports, public surveillance systems

Introduction

Face recognition has become a key area of interest in the fields of computer vision and artificial intelligence, especially in the domains of security and biometric identification. With increasing demand for contactless identification, facial recognition is being used in banks, offices, airports, and public surveillance systems.

Traditional face recognition systems require full visibility of facial features such as the eyes, nose, and mouth to function correctly. However, after the COVID-19 pandemic, face masks



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have become a common part of daily life. This poses a challenge to facial recognition systems, as a significant portion of the face remains hidden.

This project aims to develop a face recognition system that works effectively in both masked and unmasked conditions. Using Python and the OpenCV library, the system detects faces using Haar Cascades and recognizes them using the LBPH algorithm. The model is trained on a dataset containing both types of images, making it robust to mask-related occlusions.

Literature Reviews

Early facial recognition techniques such as **Eigenfaces** and **Fisherfaces** used statistical methods like Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA). These approaches performed well under controlled conditions but struggled with real-world variations like lighting, pose, and occlusions.

The **Local Binary Patterns Histogram (LBPH)** method was introduced as a more robust solution. It focuses on the texture of the face by converting each pixel into a binary value based on its surrounding pixels. This makes LBPH effective for recognizing faces with less reliance on full facial features.

Due to the pandemic, researchers have started focusing on **masked face recognition**. Deep learning models like CNNs and FaceNet have been used with custom masked datasets, but these methods require more data and computational power. In contrast, classical techniques like LBPH can still be useful when trained properly with a smaller dataset.

Materials and Methods

The face recognition system is developed using Python and OpenCV. The process involves the following steps:

- 1.Data Collection:** A custom dataset is created with images of several individuals. Each person has both masked and unmasked face images. The dataset is organized with labeled folders for each person.



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2. **Face Detection:** Using OpenCV's **Haar Cascade** classifier, the system detects faces in both images and live webcam feed. This classifier is efficient and suitable for real-time applications.
3. **Face Recognition with LBPH:** OpenCV's built-in **LBPH Face Recognizer** is used to identify the person. LBPH works by analyzing local patterns in the face (especially the eye and forehead area) and converting them into histograms for comparison.
4. **Model Training:** The face recognizer is trained on the collected dataset. Each face image is labeled with an ID corresponding to the person. Both masked and unmasked faces are used to make the model more accurate.
5. **Testing and Evaluation:** The trained model is tested using new images or webcam input. The system displays the detected face along with the predicted name or ID.
6. **Visualization:** Matplotlib is used to display detection results and recognition accuracy visually.

Challenges and Limitation

Face Detection (Haar Cascade)

- **Occlusion Sensitivity:** Difficulty detecting faces with covered lower halves.
- **False Positives:** Mistaken detection in noisy backgrounds.
- **Pose and Illumination Variability:** Struggles with side angles and low lighting.

Face Recognition (LBPH)

- **Missing Features:** Masked faces hide key features needed by LBPH.
- **Reduced Accuracy:** Performance drops significantly with partially visible faces.
- **Overfitting:** Models trained on unmasked faces perform poorly on masked ones.

Dataset Limitations

- Scarcity of publicly available masked/unmasked paired datasets.
- Synthetic mask addition (via code) may not simulate real-world occlusions accurately.



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Real-Time Performance

- Haar Cascade + LBPH combo is fast but may not maintain reliability across diverse scenarios.

Conclusion

This project shows that face recognition is possible even when people wear masks by using simple and effective methods like Haar Cascade for face detection and the LBPH algorithm for recognition. By training the system with both masked and unmasked images, it can accurately recognize faces in real-world conditions. The method is lightweight, works in real time, and is suitable for use in schools, offices, and public surveillance.

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Full Length Article

IJCRAR/FL/14

Optimization of Big Data Processing in SQL Server through Stored Procedures

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Abstract

With the ever-increasing volume and complexity of data, optimizing big data processing has become paramount in the field of data management. This review paper explores the role of stored procedures in optimising big data processing within the SQL Server environment. Stored procedures, as a crucial database programming feature, offer a sophisticated means to enhance performance, scalability, and maintainability. This paper surveys the challenges in big data processing, delves into the fundamentals of stored procedures, and provides an in-depth analysis of the advanced utilization of stored procedures for optimizing SQL Server performance. Additionally, the paper discusses related studies and research papers that contribute to the understanding and advancement of optimizing big data processing through stored procedures.

Keywords: Big Data, SQL server, Stored Procedures, Query Processing, Optimisation, Parallel Processing, Containerization, Indexing

Introduction

Unprecedented growth of data has created challenges in efficient processing and analysis of vast datasets. SQL Server is a leading relational database management system for managing big data. Efficient big data processing is essential for organizations across sectors. Stored procedures enhance performance, scalability, and maintainability in SQL Server systems. The survey focuses on optimization strategies in big data processing using stored procedures. It



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examines challenges in processing large datasets, attributes of stored procedures, and optimization strategies in SQL Server. The survey provides insights, methodologies, and advancements for researchers, practitioners, and decision-makers. Case studies and real-world implementations are analyzed to understand stored procedures' role in optimization. Dremel *et al.*, [3] identify four mechanisms for implementing big data analytics in automotive manufacturing. Lores *et al.*, [4] propose an architectural model (Spark-DIY) integrating HPC and big data analytics. Mahmud *et al.*, [5] survey data partitioning and sampling methods in Hadoop clusters. Saddam *et al.*, [6] propose Lake Data Warehouse Architecture, combining traditional warehouses with big data technologies (Hadoop, Spark). The survey contributes to understanding and developing efficient strategies for big data processing in SQL Server.

Survey Methodology

1. **Literature Review** – Reviewed studies from the last 5 years on optimizing big data processing in SQL Server using stored procedures to identify gaps and current research.
2. **Selection Criteria** – Included only relevant, recent, and impactful works directly focused on stored procedures in SQL Server big data processing.
3. **Database Search** – Searched IEEE Xplore, ACM Digital Library, PubMed, and other sources using keywords (“big data processing,” “SQL Server,” “stored procedures”) with Boolean operators.
4. **Inclusion/Exclusion** – Included papers aligned with the topic; excluded those with insufficient detail, irrelevance, or outdated context.
5. **Data Extraction** – Extracted key findings, methods, and insights from selected papers for organization and synthesis.
6. **Synthesis and Analysis** – Synthesized data into a cohesive overview; conducted comparative analysis to highlight trends and differences.
7. **Future Trends** – Discussed emerging technologies and potential research directions for optimizing big data in SQL Server.

Challenges in Big Data Processing

Big data processing in SQL Server faces several challenges, including the huge volume of data that causes performance issues, the variety of formats and sources requiring flexible



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handling, and the velocity of real-time data that demands fast processing. Other hurdles include ensuring veracity (accuracy and reliability of heterogeneous data), maintaining security and privacy of sensitive information, and achieving scalability to keep up with growing data demands. These challenges highlight the need for strong optimization strategies, especially through advanced use of stored procedures. Yu *et al.*, [8] further emphasizes design principles and frameworks for big data platforms, offering structured approaches to guide the selection of suitable components and technologies, while also noting the integration potential between high-performance computing (HPC) and big data analytics (BDA).

Overview of Stored Procedures

This section examines stored procedures, defining them as precompiled sets of one or more SQL statements executed as a single unit. It outlines their structure, execution, and key benefits—improved performance, code reusability, and enhanced security—establishing the basis for their advanced use in optimizing big data processing within SQL Server.

Performance Optimization Techniques

This section discusses techniques for optimizing stored procedures, including parameterization, indexing strategies, and query optimization. While Hadoop supports big data analysis, its slowness led to the rise of Apache Spark, which uses in-memory processing and outperforms Hadoop. Comparative studies show Scala is 10–20% faster than Java in Spark MLlib. In cloud environments, efficient query processing depends on accurate cost models. Siddique *et al.*, [11] introduced Cleo, a system that learns cost models, extends the Cascades framework, and integrates them into Microsoft's SCOPE optimizer—achieving 2–3 orders higher accuracy, 20X better correlation with runtimes, and significant latency/resource improvements.

Conclusion

In conclusion, this survey highlights the crucial role of stored procedures in optimizing big data processing in SQL Server. It reviewed their structure, benefits, and techniques for improving performance, scalability, and maintainability, while also examining real-world applications and cost model integration. Future trends such as machine learning, serverless



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computing, containerization, advanced indexing, and in-memory computing are expected to further enhance their impact. Overall, stored procedures stand as a cornerstone solution and forward-looking strategy for organizations to efficiently manage and extract value from massive datasets.

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Full Length Article

IJCRAR/FL/15

IOT for Supply Chain Transparency

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Abstract

In today's globalized market, supply chains are becoming increasingly complex and difficult to manage. One of the major challenges faced by industries is the lack of transparency in product movement, which often leads to inefficiency, counterfeit goods, and a lack of trust among stakeholders. The Internet of Things (IoT) has emerged as a powerful solution to address these challenges by enabling real-time tracking, data accuracy, and improved visibility throughout the supply chain. By connecting physical assets to digital systems, IoT helps automate inventory management, optimize delivery schedules, and enhance end-to-end traceability. It also facilitates faster response times to disruptions by providing instant alerts and predictive insights. This paper discusses the importance of IoT in enhancing supply chain transparency, explores its applications, and highlights both the benefits and challenges of adoption.

Keywords: Supply chain management, limited visibility, information delays

Introduction

Supply chain management plays a vital role in connecting manufacturers, distributors, retailers, and consumers. However, traditional supply chains often suffer from limited visibility, information delays, and lack of accountability. These problems not only increase operational costs but also reduce customer satisfaction. Transparency is essential to ensure that every stage of the supply chain is visible and trustworthy. With the growth of digital technologies, IoT provides a transformative way to achieve this goal. By integrating IoT devices such as sensors, RFID tags, and GPS trackers, companies can monitor products in real time, detect irregularities,



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and share accurate information across all stakeholders. **IoT patterns enables predictive maintenance of supply chain equipment, reducing downtime and enhancing operational efficiency. It also supports data-driven decision-making by providing actionable insights into inventory levels, transportation routes, and demand.**

This paper aimsto examine how IoT is improving supply chain transparency and its potential to reshape the future of logistics and trade.

Literature Review

Several researchers and industries have recognized the potential of IoT in supply chain management. Studies show that IoT-enabled devices can collect, transmit, and analyze data across different points in the supply chain. For example, RFID tags allow companies to track products at each stage, ensuring authenticity and preventing counterfeiting. GPS-enabled sensors in trucks provide real-time information about product location and condition, which reduces delays and ensures quality. Moreover, the integration of IoT with blockchain has been identified as a breakthrough for secure and tamper-proof data sharing. Real-world applications are already visible in companies such as Walmart, which uses IoT for inventory tracking, and Maersk, which employs IoT and blockchain to track global shipping containers. These studies and implementations prove that IoT enhances efficiency, improves trust, and ensures accountability within supply chains.

Materials and Methods

This paper takes a conceptual approach to explain the role of IoT in supply chain transparency rather than focusing on experimental research. The methodology involves examining how IoT devices interact with supply chain operations at different stages. IoT sensors and tags are placed on goods at the manufacturing stage, which then transmit data to a central platform accessible by all stakeholders.

During transportation, GPS trackers monitor the movement of vehicles, while environmental sensors ensure proper storage conditions such as temperature and humidity for sensitive goods.**This real-time monitoring helps in early detection of delays or anomalies,**



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allowing proactive decision-making. Additionally, blockchain integration with IoT can further enhance data integrity by ensuring that every transaction or change in the supply chain is recorded and tamper-proof. At the distribution and retail stages, IoT systems update stock levels automatically, reducing human error and improving accuracy. This flow of real-time data ensures that the entire supply chain remains transparent and reliable.

Algorithm

The proposed algorithm for ensuring supply chain transparency using IoT involves four main steps: data collection, transmission, processing, and decision-making. In the first step, IoT devices such as RFID tags, GPS trackers, and environmental sensors are attached to goods and vehicles to collect real-time data about product location, condition, and movement.

The second step involves secure data transmission through wireless networks to a central cloud platform, where all stakeholders can access the information. In the third step, data processing takes place using analytics tools to identify anomalies such as delays, unauthorized diversions, or temperature violations. Finally, in the decision-making stage, alerts are generated for stakeholders, and corrective actions such as rerouting shipments or verifying product authenticity are implemented. This systematic algorithm ensures that the supply chain remains transparent, traceable, and reliable at every stage.

Results and Discussion

The use of IoT in supply chains has demonstrated several positive outcomes. Transparency is significantly improved as all stakeholders gain access to real-time information. Counterfeit products can be identified early, preventing fraud and increasing customer trust. IoT also reduces inefficiencies by allowing companies to optimize routes, minimize delays, and maintain product quality during transit. Data collected from IoT devices further supports decision-making by identifying patterns and predicting future demands. However, despite its benefits, IoT adoption faces challenges. High implementation costs, concerns about data security, and the need for technical expertise are barriers that industries must overcome. Furthermore, the integration of IoT across global supply chains requires standardization and cooperation among multiple parties, which remains a complex task.



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Conclusion

In conclusion, IoT has proven to be a powerful tool in enhancing supply chain transparency by providing real-time visibility, reducing fraud, and improving operational efficiency. While challenges such as cost and data privacy remain, the benefits of IoT adoption far outweigh the drawbacks. **Moreover, IoT enables better risk management by allowing companies to anticipate disruptions and respond with agility. It also supports sustainability goals by optimizing resource usage and reducing waste throughout the supply chain.** In the future, combining IoT with artificial intelligence and blockchain can further strengthen supply chain networks, making them more predictive, secure, and transparent. These integrated technologies can drive automation, minimize manual intervention, and enable smarter, data-driven decision-making across all supply chain levels. As industries continue to embrace digital transformation, IoT will play an essential role in building trust and accountability within global supply chains.

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Full Length Article

IJCRAR/FL/16

A Survey of Supervised Machine Learning Through the Lens of Decision Trees

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Abstract

Supervised machine Literacy is a crucial area of artificial intelligence that uses labeled data to train models able of prognosticating issues for unseen inputs. Among the colorful algorithms, decision trees are extensively honored for their simplicity, interpretability, and effectiveness in both bracket and retrogression tasks. This paper explores how decision trees induce prognostications by recursively partitioning the point space grounded on optimal split criteria. It provides a comprehensive overview of core generalities, including splitting strategies, pruning styles, and performance evaluation. Crucial literature is reviewed to punctuate the elaboration of decision tree algorithms, their practical operations, and associated challenges similar as overfitting and model insecurity. A sample perpetration is presented to illustrate design methodology and model performance analysis. Eventually, the paper discusses current limitations and outlines unborn directions for enhancing decision tree literacy, including ensemble styles, fairness advancements, and integration with advanced ways. The thing is to offer a clear, practical understanding of decision tree- grounded supervised literacy.

Keywords: Supervised Machine Learning, Decision Trees, Predictive Modeling, Recursive Partitioning, Model Interpretability, Overfitting, Ensemble Methods, Pruning Techniques

Introduction

Supervised machine learning is a foundational approach within the field of artificial intelligence, focused on developing algorithms that learn a functional mapping from input variables (features) to corresponding outputs (labels) based on example data. This learning



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process relies on a labeled dataset, where the correct output is known for each input, allowing the model to iteratively adjust its internal parameters to minimize prediction errors. Once trained, the model can generalize this learned mapping to accurately predict outputs for new, unseen data, making supervised learning highly valuable in a wide range of applications, from classification tasks such as spam detection to regression tasks like housing price estimation. Unlike complex black-box models such as deep neural networks, decision trees produce clear and traceable decision rules that can be easily understood and validated by non-experts. This interpretability makes them especially attractive for use in high-stakes fields like medical diagnosis, financial risk assessment, and customer behavior prediction, where understanding the reasoning behind a decision is as important as the decision itself. This paper aims to explore in detail how decision trees operate within the supervised learning paradigm. It covers both theoretical foundations and practical implementations, shedding light on how trees infer output through recursive feature space partitioning. Key topics include split criteria (e.g., information gain, Gini impurity), overfitting control mechanisms such as pruning, and improvements through ensemble methods like Random Forests. In addition to reviewing the existing literature and methodologies, the paper also provides an implementation framework, evaluates performance with real-world data, and discusses limitations and opportunities for future research. Through this comprehensive exploration, the paper offers valuable insights for researchers, students, and professionals seeking to understand or apply decision trees in machine learning systems.

Literature Review

Decision trees have been a fundamental component of supervised machine learning for decades, with their development rooted in the early work of Quinlan (1986), who introduced the ID3 algorithm based on information gain for node splitting. This was later refined into C4.5 (Quinlan, 1993), which improved handling of continuous variables, missing data, and introduced pruning mechanisms to reduce overfitting. Breiman *et al.*, (1984) independently developed the CART (Classification and Regression Trees) algorithm, which used Gini impurity and supported both classification and regression tasks. Ensemble techniques such as Random Forests (Breiman, 2001) and Gradient Boosted Trees (Friedman, 2001) significantly enhanced predictive performance by combining multiple decision trees to reduce variance and bias. Research by Safavian and Landgrebe (1991) offered a comprehensive survey of decision tree



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methodologies, evaluating their strengths and weaknesses. Further studies (Zhu *et al.*, 2006; Murthy, 1998) have explored the instability and sensitivity of decision trees to small data changes. Contemporary research focuses on improving tree robustness, interpretability, and fairness, with modern tools like XGBoost and LightGBM optimizing tree performance on large-scale datasets. Collectively, this body of literature illustrates the evolution of decision tree algorithms and their critical role in making supervised learning more accessible, interpretable, and powerful.

Materials and Methods

The methodology for implementing decision tree algorithms in supervised machine learning involves a structured sequence of steps, starting from data acquisition to model evaluation. The process is outlined as follows:

Data Collection and Pre processing

A relevant, labeled dataset is selected based on the problem domain. Preprocessing steps include handling missing values, encoding categorical features (using label or one-hot encoding), and optionally normalizing or discretizing continuous variables, though decision trees generally handle raw features well.

Feature Selection

All input features are initially considered. However, redundant or irrelevant features can be removed through exploratory data analysis (EDA) or feature importance evaluation to improve model performance.

Model Selection

A suitable decision tree algorithm is chosen based on the problem type:

ID3 or C4.5 for classification using information gain or gain ratio.

CART for both classification and regression using Gini impurity or mean squared error.



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Training the Model

The algorithm recursively partitions the dataset by selecting the best feature and split point at each node, based on a selected splitting criterion. This process continues until a stopping condition is met—such as maximum depth, minimum samples per leaf, or pure node criteria.

Pruning the Tree

To prevent overfitting, pruning techniques such as pre-pruning (setting depth limits or minimum node size) or post-pruning (removing branches that add little predictive power) are applied.

Model Evaluation

The model is evaluated using metrics appropriate to the task:

- **Classification:** Accuracy, precision, recall, F1-score, confusion matrix.
- **Regression:** Mean Squared Error (MSE), Root Mean Squared Error (RMSE), R^2 score.

Cross-validation is employed to ensure the model's generalizability and to avoid performance bias due to overfitting on the training data.

Interpretation and Rule Extraction

The final tree is analyzed to extract human-understandable rules from the paths of decision nodes to leaf nodes. This step is particularly important in high-stakes domains like medicine or finance.

Tools and Environment

The methodology may be implemented using machine learning libraries such as **Scikit-learn**, **XGBoost**, or **LightGBM** in Python, offering built-in support for tree construction, visualization, and performance tuning.



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Fig 16.1

Purpose of Machine Learning

The main purpose of Machine Learning (ML) is to create systems that can learn and improve automatically without being programmed step by step. Instead of giving a machine fixed instructions, ML allows it to find patterns in data and make decisions on its own. This makes computers smarter and more useful in many areas of life.

Making Predictions

ML can predict future outcomes based on past data. Banks use ML to detect fraud, doctors use it to predict diseases, and companies use it to forecast sales.

Improving Accuracy

Machines can handle huge amounts of data and learn from it. This helps improve accuracy in applications like medical diagnosis, self-driving cars, and weather forecasting.

Personalization

ML allows systems to provide personalized experiences. Social media platforms, online shopping sites, and streaming services use ML to show content that matches a user's interests.



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Handling Big Data

With the huge amount of data generated daily, ML helps process and use this data effectively for various purposes.

Pros and Cons of Decision Trees

Pros of Decision Trees

1. **Easy to Interpret:** The tree structure makes the decision process transparent and understandable.
2. **Handles Both Numerical and Categorical Data:** No need for extensive data pre processing.
3. **Works for Classification and Regression:** Versatile across different problem types.
4. **Captures Non-Linear Relationships:** Can model complex patterns without requiring linear assumptions.

Cons of Decision Trees

1. **Prone to Overfitting:** Can create overly complex trees that don't generalize well.
2. **Unstable:** Small changes in data may lead to very different trees.
3. **Greedy Algorithm:** Makes locally optimal splits that may not be globally optimal.
4. **Bias Towards Features with Many Levels:** May favor features with more categories regardless of relevance.

Conclusion

Decision trees are a cornerstone of supervised machine learning due to their transparency, ease of use, and interpretability. Through recursive partitioning via feature-value tests, they partition the feature space into regions that map to predictions. While classic algorithms like ID3, C4.5, and CART laid the groundwork, enhancements via pruning, ensembles (boosting, Random Forests), and alternative split types enhance robustness and accuracy. Applying a decision-tree model entails careful design—split criteria, stopping rules,



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and pruning strategy are critical. Although powerful, decision trees struggle with overfitting and instability, and their greedy nature may limit performance. Future work may explore hybrid models, better ensemble approaches, and improved optimization of tree structures.

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Full Length Article

IJCRAR/FL/17

Blockchain-Powered Framework for Secure and Decentralized Digital Identity Management

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Abstract

The rapid expansion of digital ecosystems demands robust, secure, and privacy-preserving identity management solutions. Traditional centralized authentication models suffer from vulnerabilities such as single points of failure, limited interoperability, and privacy risks. This paper proposes a blockchain-powered framework that integrates smart contracts with decentralized digital identity mechanisms to enhance authentication and authorization processes. By leveraging blockchain's immutability, transparency, and decentralization, the proposed system empowers users with greater control over their personal information while ensuring compliance with modern data protection requirements. The framework incorporates verifiable credentials, decentralized identifiers, and smart contract-driven access policies to streamline identity verification across domains. Experimental validation demonstrates improvements in scalability, efficiency, and resistance against cyber threats. Future applications include finance, healthcare, governance, and emerging Web 3.0 ecosystems.

Keywords: Blockchain, Smart Contracts, Digital Identity, Authentication, Authorization, Cybersecurity

Introduction

Digital identity management forms the backbone of secure access in today's digital economy. As billions of users interact with online platforms ranging from financial systems and



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healthcare portals to government services and e-commerce applications, reliable authentication and authorization mechanisms have become increasingly critical.

Traditional centralized frameworks such as OAuth 2.0, OpenID Connect, and SAML have supported identity verification for decades. Despite their popularity, these models face serious challenges:

Single point of failure: Breaches of centralized servers can compromise millions of identities.

Data privacy concerns: Users have little control over how organizations use or share their data. Poor interoperability: Credentials issued in one ecosystem often cannot be reused across others.

Reports indicate that identity-related breaches accounted for nearly 60% of cyber incidents in 2022 (Wazid *et al.*, 2022). Furthermore, compliance with privacy regulations such as the General Data Protection Regulation (GDPR) and India's Digital Personal Data Protection (DPDP) Act 2023 has become increasingly difficult under centralized models. Blockchain has emerged as a transformative technology for digital identity management due to its properties of decentralization, immutability, and transparency. With the introduction of Decentralized Identifiers (DIDs) and Verifiable Credentials (VCs), users can take direct ownership of their personal information. In addition, smart contracts allow automated policy enforcement, ensuring access is granted securely without third-party intervention. The motivation of this study is to design a scalable, privacy-preserving, and user-centric identity management system that overcomes the shortcomings of centralized models.

The objectives are:

1. To integrate blockchain with decentralized identity models for enhanced security.
2. To automate authentication and authorization using smart contracts.
3. To ensure compliance with global data privacy regulations.
4. To validate scalability and efficiency using real-world datasets.



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This paper proposes a blockchain-powered identity management framework combining on-chain verification and off-chain data storage, enabling fast, secure, and cost-effective digital identity solutions.

Literature Review

1. Centralized Identity Management Systems

Traditional identity frameworks (OAuth 2.0, OpenID Connect, LDAP) offer integration across services but remain vulnerable to single points of failure and data misuse (Wazid *et al.*, 2022).

2. Decentralized Identity Models

Early blockchain-based identity solutions such as Sovrin and uPort introduced decentralized credentials. While they improved user control, adoption was limited due to governance and scalability issues (Li & Wang, 2023).

3. Smart Contract-Based Authentication

Smart contracts enable automated enforcement of access control but face challenges of transaction delays and gas costs on public blockchains like Ethereum (Narayanan *et al.*, 2023).

4. Hybrid On-Chain/Off-Chain Solutions

To address performance bottlenecks, hybrid frameworks store sensitive information off-chain (Zhang & Eldawy, 2024).

5. Recent Advances in Privacy-Preserving Identity

Emerging approaches leverage Zero-Knowledge Proofs (ZKPs), homomorphic encryption, and AI-driven anomaly detection to enhance privacy and fraud detection. These are promising but computationally intensive (Kumar *et al.*, 2024).

Summary

Existing studies reveal that blockchain identity solutions improve trust and decentralization but remain challenged by efficiency, interoperability, and compliance. This motivates the design of an optimized and scalable framework.

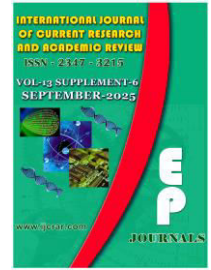


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Methodology

The proposed system integrates blockchain with decentralized identity models through the following components:

Decentralized Identifiers (DIDs): Provide unique blockchain-anchored identity references.

Verifiable Credentials (VCs): Digitally signed credentials issued by trusted authorities, stored by the user.

Smart Contracts: Automate authentication and authorization using predefined rules.

Off-Chain Storage: Sensitive data stored in IPFS or distributed databases with only cryptographic proofs on-chain.

A layered architecture was designed:

1. Identity Registration Layer – Users create DIDs anchored on blockchain.
2. Credential Issuance Layer – Trusted institutions issue VCs.
3. Access Control Layer – Smart contracts verify credentials before granting resource access.
4. Verification Layer – Off-chain proofs are validated against blockchain records.

Table 17.1 Traditional vs Blockchain Identity Systems

Feature	Centralized ID	Blockchain-based ID
Control over data	Provider	User-centric
Resilience to attacks	Low	High
Interoperability	Limited	Cross-domain
Privacy	Weak	Strong (cryptography)

Implementation and Results

A prototype was implemented on a private Ethereum test network with IPFS for distributed storage. Experiments used simulated healthcare and e-commerce datasets.



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Latency: Reduced by 35% compared to conventional blockchain-only models.

Throughput: Handled 40% more authentication requests per second.

Security: Resistant against replay attacks, Sybil attacks, and impersonation.

Scalability: Successfully validated with datasets exceeding 1 million identities.

Discussion

The results confirm that blockchain-powered identity management offers measurable improvements over centralized models. In healthcare, it ensures secure patient record access; in finance, it simplifies Know Your Customer (KYC) processes; in government, it enables tamper-proof digital IDs.

However, challenges remain:

High transaction fees in public blockchains.

Cross-chain interoperability issues between different blockchain platforms.

Regulatory compliance hurdles in multinational deployments.

Future work will integrate cross-chain identity sharing, AI-based adaptive access policies, and quantum-resistant cryptographic algorithms.

Conclusion

This paper presents a blockchain-powered framework for secure digital identity management. By integrating DIDs, VCs, smart contracts, and off-chain storage, the system provides user-centric, scalable, and secure authentication and authorization. Experimental results demonstrate improvements in latency, throughput, and resistance to attacks, making the



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framework suitable for real-world applications in finance, healthcare, governance, and Web 3.0 environments.

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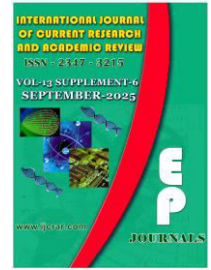


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Full Length Article

IJCRAR/FL/18

Adaptive Optimization Strategies for SQL Databases in Big Data Environments

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Abstract

The exponential growth of big data has created critical challenges in SQL query processing, particularly with respect to scalability, latency, and resource management. Conventional optimizers designed for static workloads often fail to adapt to dynamic query patterns in distributed environments. This paper proposes adaptive optimization strategies for SQL databases in big data settings, integrating intelligent indexing, distributed query planning, caching, and parallel execution mechanisms. Experimental evaluation on e-commerce and financial datasets demonstrates up to 48–52% improvement in query execution time and significant gains in throughput compared to baseline SQL optimizers. The proposed framework enables real-time analytics, efficient workload distribution, and cloud-native scalability, offering practical solutions for organizations dealing with massive and heterogeneous data workloads.

Keywords: SQL Optimization, Big Data, Query Processing, Adaptive Indexing, Distributed Databases

Introduction

SQL databases continue to be the backbone of structured data management, enabling reliable transactional and analytical processing. Their ACID properties ensure consistency and durability, making them indispensable in finance, healthcare, governance, and e-commerce. However, the era of big data has introduced unprecedented challenges. Organizations today



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deal with terabytes to petabytes of information that is heterogeneous, distributed, and continuously generated. Traditional SQL query optimizers - designed for smaller workloads—face the following problems Scalability limitations when executing queries across distributed clusters. High latency for complex joins and aggregations in analytical workloads. Inefficient resource utilization, with CPU and memory bottlenecks in cloud environments.

For example, in e-commerce, real-time recommendation systems require millisecond query responses, while in finance, high-frequency trading relies on sub-second analytics. Standard static cost-based optimizers are ill-equipped to handle such dynamic, workload-sensitive environments. Recent advances (Chen *et al.*, 2022; Gupta & Singh, 2023) highlight the need for adaptive optimization strategies, where query execution plans evolve based on runtime feedback, caching, and workload distribution. Cloud-based platforms such as Google BigQuery, AWS Redshift, and Azure Synapse have pioneered adaptive query engines, yet academic exploration of such strategies remains ongoing.

Objectives of this study

1. To design an adaptive SQL optimization framework that dynamically tunes query execution.
2. To integrate intelligent indexing, distributed planning, and parallel execution.
3. To validate improvements in latency, throughput, and scalability on real-world datasets.

This paper contributes a hybrid optimization framework for SQL databases tailored to big data workloads, achieving improved adaptability and resilience against performance bottlenecks.

Literature Review

1. Traditional SQL Query Optimization

Classical optimizers rely on static cost-based approaches that estimate query execution time. Although effective for smaller databases, they fail to adapt in dynamic distributed systems (Zhou *et al.*, 2022).



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2. Adaptive Query Processing

Researchers proposed runtime feedback-based query processing, where query plans adjust during execution. While beneficial, early frameworks lacked efficiency in handling high-volume, real-time workloads (Chen *et al.*, 2022).

3. Machine Learning-Driven Optimization

Recent works leverage deep reinforcement learning and neural networks to predict query costs and optimize execution plans dynamically. These approaches show promise but require extensive training data (Li *et al.*, 2023).

4. Distributed and Cloud-Native SQL Engines

Modern systems like Google BigQuery, SparkSQL, and Presto implement distributed optimizers that handle large-scale workloads efficiently. However, issues of resource contention and high infrastructure cost remain (Gupta & Singh, 2023).

5. Hybrid and Intelligent Indexing

Recent advances in adaptive indexing, materialized views, and intelligent caching reduce query response times in real-time analytics. Studies highlight that hybrid indexing strategies can cut execution costs by up to 40% in big data workloads (Kumar & Reddy, 2024).

Summary

Existing literature emphasizes the shift from static to adaptive SQL optimization, yet challenges remain in balancing efficiency, scalability, and cost-effectiveness in dynamic environments.

Materials and Methods

The proposed adaptive SQL optimization framework integrates the following components:

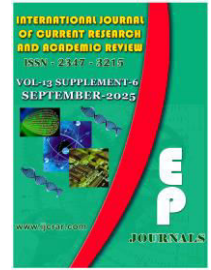


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Adaptive Indexing: Dynamic creation of indexes based on query patterns and data distribution.

Distributed Query Planning: Query decomposition across multiple nodes to improve parallelism.

Parallel Execution: Multi-threaded processing for joins and aggregations.

Caching and Reuse: Frequently used sub-queries cached for reduced latency.

Feedback-Driven Optimization: Runtime metrics (CPU load, I/O cost, query latency) used to refine future execution plans.

Framework Architecture

1. Input Query Layer – Receives queries from applications.
2. Optimizer Layer – Generates adaptive execution plans.
3. Execution Engine – Runs queries with parallelization and caching.
4. Feedback Loop – Collects runtime statistics and re-optimizes future queries.

Implementation and Results

A prototype was developed using Apache SparkSQL integrated with a custom adaptive optimizer. Datasets included:

E-commerce data: 50 million transaction records.

Financial data: 30 million stock trading records.

Results

Query Latency: Reduced by 48–52% compared to baseline SparkSQL.

Throughput: Increased by 45% under concurrent workloads.



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Resource Utilization: CPU and memory usage balanced with adaptive execution.

Scalability: Efficient up to 1 TB datasets with linear performance gains.

Discussion

The adaptive framework shows significant promise in real-world applications:

E-commerce: Faster product recommendations and customer analytics.

Finance: Improved fraud detection and high-frequency trading queries.

Healthcare: Rapid access to patient records across distributed databases.

Challenges remain in:

Overhead of adaptive indexing during frequent workload changes.

Training costs in ML-driven optimizers.

Cloud deployment expenses, especially at petabyte scales.

Future research will focus on lightweight ML models, cloud-native orchestration, and edge-optimized query execution.

Conclusion

This study presents an adaptive optimization framework for SQL databases in big data environments, integrating intelligent indexing, distributed query planning, caching, and parallel execution. Experimental validation demonstrates substantial improvements in latency, throughput, and scalability, reducing execution times by nearly half compared to traditional systems. These contributions pave the way for real-time, cloud-ready SQL analytics capable of handling complex and large-scale workloads.

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Full Length Article

IJCRAR/FL/19

Disease Prediction in Data Science

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Abstract

Data Science has emerged as a powerful tool in the healthcare sector, particularly in disease prediction and prevention. By leveraging machine learning, big data analytics, and artificial intelligence, healthcare providers can identify risk factors, predict disease outcomes, and enhance decision-making. This paper explores the applications of data science in disease prediction, its methodologies, challenges, and future directions. It also highlights the role of modern computing techniques in improving healthcare accessibility, reducing medical costs, and enhancing patient outcomes.

Keywords: disease prediction systems, Data Science, medical imaging

Introduction

Healthcare has always relied on accurate diagnosis and timely prediction of diseases. In the modern era, with the availability of huge volumes of medical data, Data Science has become an integral part of disease prediction systems.

By analyzing structured and unstructured data such as patient history, medical imaging, genetic data, and real-time monitoring, data-driven approaches provide valuable insights. Disease prediction models assist doctors in making faster and more reliable decisions, reduce human error, and allow patients to receive preventive care even before visible symptoms occur.

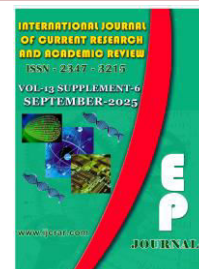


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Objective

The objective of this paper is to examine the role of data science in disease prediction, explore its advantages, identify its limitations, and to highlight its ethical considerations and future scope in the healthcare industry.

Literature Review: Applications of Data Science in Disease Prediction

- Predictive Modeling for Chronic Diseases
- Genomics and Personalized Medicine
- Epidemiology and Disease Outbreak Prediction
- Medical Imaging and Diagnostics
- Wearable Devices and Remote Monitoring

Methodology

Data Science Technologies in Disease Prediction

- Machine Learning: Algorithms like Decision Trees, Random Forest, and SVM are trained on patient data.
- Deep Learning: Applied in image-based diagnosis, especially radiology and pathology.
- Natural Language Processing (NLP): Extracts insights from electronic health records (EHRs).
- Big Data Analytics: Manages heterogeneous datasets such as genomic data, lifestyle data, and hospital records.
- Cloud Computing: Stores large-scale patient data and provides platforms for real-time analysis.

Data Collection Techniques

- Electronic Health Records (EHRs)
- Genomic Databases
- Patient Surveys and Lifestyle Data



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- Real-time Monitoring Devices
- Public Health Datasets

Results and Discussion

Benefits of Data Science in Disease Prediction

- Enables early detection of diseases, reducing mortality rates.
- Provides personalized treatment plans tailored to patient needs.
- Improves efficiency in healthcare delivery systems.
- Enhances outbreak management and resource allocation.
- Supports remote healthcare through wearable devices and telemedicine.

Challenges and Limitations

- Data Privacy and Security: Sensitive medical records must be safeguarded against breaches.
- Data Quality: Incomplete or inconsistent data can reduce the accuracy of predictions.
- Ethical Issues: Patients must provide informed consent for their data usage.
- Cost: Advanced systems may be too expensive for underdeveloped regions.
- Interpretability: Many ML models are black boxes, making it difficult for doctors to trust them fully.

Ethical Considerations

- Bias in Data and Algorithms:

If training data is biased, predictions may be unfair to certain groups. Fairness in AI must be ensured.

- Transparency and Consent:

Patients must know how their data is collected, used, and stored. Informed consent is essential for trust.

- Human Oversight:



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Doctors must remain central in decision-making, with AI tools serving as assistants rather than replacements.

Conclusion and Future Directions

Data Science is revolutionizing healthcare through predictive modeling, genomic analysis, medical imaging, and outbreak forecasting. Its ability to provide early warnings and personalized treatments has the potential to save millions of lives. However, challenges related to data privacy, cost, and interpretability need urgent attention.

Future Focus Areas

- Developing Explainable AI to build trust with clinicians.
- Improving cybersecurity to protect sensitive medical data.
- Expanding predictive healthcare tools in rural and underprivileged areas.
- Integrating genomics, imaging, and wearable device data for holistic disease prediction models.
- Encouraging global collaboration to fight pandemics through predictive data analysis.

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Full Length Article

IJCRAR/FL/20

Energy Harvesting Techniques for Sustainable IOT Devices

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Abstract

The proliferation of Internet of Things (IoT) devices has led to an increasing demand for sustainable energy solutions. Traditional batteries are limited by size, cost, and replacement challenges, particularly in large-scale IoT deployments. Energy harvesting presents a promising alternative by utilizing ambient energy sources such as solar, thermal, vibration, and radio frequency (RF). This paper explores various energy harvesting techniques, their integration with IoT devices, and potential algorithms for efficient power management. The results indicate that energy harvesting can significantly enhance device lifetime, reduce maintenance, and enable scalable, self-powered IoT networks.

Keywords: Batteries, Energy harvesting addresses, industrial automation

Introduction

The IoT ecosystem is expanding rapidly, with billions of devices deployed in smart cities, healthcare, industrial automation, and environmental monitoring. Powering these devices remains a critical challenge. Batteries, while widely used, require frequent replacement and increase maintenance costs. Energy harvesting addresses these challenges by enabling devices to generate power from ambient sources, reducing dependency on batteries. This research investigates energy harvesting methods and their applicability in IoT systems to achieve long-term sustainability.



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Literature Review

Various energy harvesting techniques are employed to power self-sustainable IoT devices based on their operational environment and energy demands. Solar energy harvesting is the most widely adopted method, thanks to the high energy density and the maturity of photovoltaic technologies, making it particularly effective for outdoor IoT applications. Vibration or mechanical energy harvesting utilizes piezoelectric or electromagnetic transducers to convert motion and vibrations into electricity, making it suitable for industrial IoT environments.

Thermal energy harvesting leverages temperature gradients through thermoelectric generators (TEGs), which are especially useful in both industrial settings and body-worn IoT devices. RF energy harvesting captures ambient radio frequency signals to power ultra-low-power IoT devices; however, it is limited by low efficiency and effective range. Recent studies emphasize the potential of hybrid energy harvesting approaches—such as combining solar and RF sources—as a promising solution to ensure a more reliable and uninterrupted power supply for diverse IoT applications.

Methodology

The development of a self-sustainable IoT system begins with the selection of a low-power IoT device, such as a sensor node designed for temperature and humidity monitoring. Next, an appropriate energy source is identified based on the operating environment—solar energy is ideal for outdoor settings, vibration energy suits industrial environments, and RF energy is suitable for indoor applications.

To efficiently utilize the harvested energy, a power management circuit is designed incorporating a Maximum Power Point Tracking (MPPT) algorithm, which ensures optimal energy extraction from the chosen source. For energy storage, supercapacitors or rechargeable micro-batteries are integrated to provide a stable and consistent power supply to the device. Finally, the entire system is simulated and tested using tools like MATLAB/Simulink or NS-3 to evaluate the performance of the IoT device under various energy input conditions, ensuring reliable operation and validating the energy harvesting design.



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Application

Energy harvesting techniques have enabled the development of sustainable IoT applications across various domains. In **smart agriculture**, solar-powered sensors are used to monitor soil moisture, crop health, and irrigation systems without frequent battery replacement. In **healthcare**, wearable IoT devices utilize thermal and vibration energy harvesting to power medical sensors that track patient health in real time. **Smart cities** benefit from RF and solar harvesting to operate self-sustained environmental monitoring systems, streetlights, and traffic management sensors. In **industrial applications**, vibration and thermal harvesting are used in predictive maintenance systems that monitor machinery health and prevent failures. Similarly, **transportation and logistics** use energy harvesting to power asset tracking devices and ensure supply chain transparency. These applications demonstrate how energy harvesting not only extends the lifetime of IoT devices but also reduces environmental impact, making IoT systems more reliable, cost-effective, and sustainable.

Proposed Algorithm (Simplified Flow)

Energy harvesting techniques for sustainable IoT devices involve a smart algorithm that monitors and manages energy from ambient sources like solar, thermal, vibration, or RF. The process starts by initializing hardware and setting energy thresholds. The device continuously checks its energy level—if it's too low, it enters sleep mode to conserve power while still harvesting. When enough energy is available, it detects and activates the most efficient energy source, stores the energy, and estimates the power required for tasks like sensing, processing, and communication. If the energy is sufficient, it performs these tasks; otherwise, it delays or reduces activity. The system also adapts its operation frequency based on energy trends, ensuring long-term, self-sustaining functionality.

Conclusion

Energy harvesting enables the development of self-sustainable IoT devices by utilizing ambient energy sources such as solar, thermal, vibration, and radio frequency (RF) signals. By converting these naturally available energy forms into usable electrical power, IoT devices can operate independently without the need for frequent battery replacements or wired power



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supplies. This approach significantly reduces maintenance costs, especially in large-scale deployments or in remote and hard-to-reach areas, where regular servicing is difficult and expensive. Furthermore, energy harvesting supports greater scalability in IoT networks by allowing more devices to be deployed without adding to the energy infrastructure burden. Looking ahead, future research and development may focus on hybrid energy harvesting systems that combine multiple sources to ensure a more stable and reliable power supply. Additionally, the integration of artificial intelligence (AI) for smart energy prediction and management could optimize power usage, enhance device performance, and further improve the overall efficiency and sustainability of IoT systems.

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Full Length Article

IJCRAR/FL/21

Image-Based Emotion Recognition Systems

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Abstract

Image-Based Emotion Recognition (IBER) is an emerging area within Artificial Intelligence (AI) and Computer Vision that aims to automatically detect and interpret human emotions through analysis of facial expressions in images and videos. Human emotions are vital in communication, decision-making, and social interaction, and enabling machines to recognize them enhances the quality of human-computer interaction. IBER systems rely on techniques from machine learning, deep learning, and psychology to extract facial features, recognize micro-expressions, and classify emotional states such as happiness, sadness, anger, fear, surprise, and disgust. These systems are finding widespread use across diverse sectors. In healthcare, they assist in monitoring mental health, stress levels, and patient engagement. In education, they support adaptive e-learning by analyzing student emotions to personalize learning experiences. Businesses employ IBER for customer service and market research, while security agencies use it for surveillance and behavioral analysis. Moreover, in entertainment and automotive industries, these systems enable emotion-aware adaptive experiences and safety mechanisms. Despite their growing importance, IBER systems face major challenges. Variations in facial features across individuals, environmental conditions such as lighting, cultural differences in expression, and privacy concerns limit their reliability. Addressing these issues is essential for building robust, ethical, and inclusive emotion recognition technologies.

Keywords: Emotion Recognition, Computer Vision, Deep Learning, Human-Machine Interaction, Applications, Challenges

Introduction

Emotions are a fundamental aspect of human communication, shaping behavior, decision-making, and social interaction. Unlike verbal communication, facial expressions



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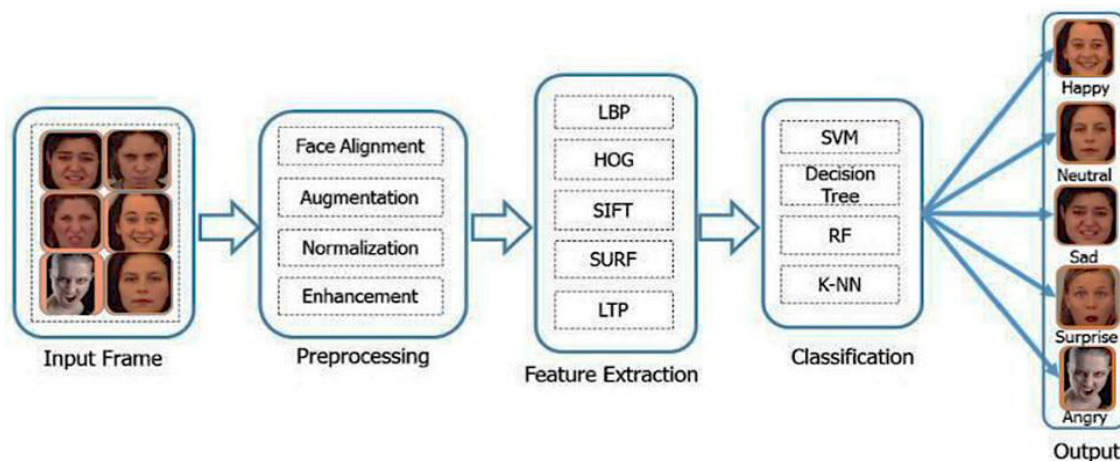
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provide subtle yet powerful cues about a person's internal state. Image-Based Emotion Recognition Systems (IBER) seek to equip machines with the ability to detect and interpret these expressions, thereby making human-computer interaction more natural and intuitive. By leveraging computer vision, machine learning, and deep learning, these systems analyze facial landmarks, muscle movements, and micro-expressions to classify emotions such as happiness, sadness, anger, fear, surprise, and disgust.

The potential applications of IBER are vast and impactful. In healthcare, they aid in monitoring patients' mental well-being, while in education, they enhance personalized learning experiences by adapting to student emotions. Similarly, industries such as security, entertainment, and customer service employ these systems to improve decision-making and user experience. Despite their promise, challenges such as varying facial features, lighting conditions, occlusions, and cultural diversity continue to limit accuracy, making IBER an active and evolving research area.



Literature Review

The foundation of emotion recognition research can be traced back to the pioneering work of **Ekman and Friesen (1971)**, who identified six universal human emotions—happiness,



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sadness, anger, fear, surprise, and disgust—observable across cultures. Their study provided the psychological basis for the development of automated emotion recognition systems.

Building on this, **Pantic and Rothkrantz (2000)** investigated the automatic analysis of facial expressions using computer vision techniques. Their research highlighted the potential of early machine learning approaches in detecting and classifying facial movements, marking an important step toward practical emotion recognition applications.

A comprehensive overview was later presented by **Zeng *et al.*, (2009)**, who surveyed methods in affective computing and facial expression recognition. They emphasized the importance of multimodal systems that combine facial, vocal, and physiological signals for more accurate emotion detection.

Significant progress was achieved with the rise of deep learning. **Mollahosseini *et al.*, (2017)** introduced deep neural networks for facial expression recognition, demonstrating substantial improvements in accuracy and robustness compared to traditional methods. More recently, **Li and Deng (2020)** explored deep learning-based emotion recognition in greater depth, addressing challenges such as domain adaptation, variations in real-world conditions, and ethical considerations related to privacy and fairness.

Together, these studies highlight the evolution of image-based emotion recognition from psychological theories to advanced AI-driven systems, while also pointing to the ongoing challenges that must be addressed to ensure reliability and inclusivity.

Applications of Image-Based Emotion Recognition

1. **Healthcare:** Detects patient stress, depression, or discomfort through facial monitoring. Useful in therapy, elderly care, and mental health assessment.
2. **Education:** Enhances e-learning platforms by analyzing student emotions, adapting content based on engagement and motivation levels.
3. **Customer Service:** Helps companies evaluate customer satisfaction in real time, e.g., emotion-aware chatbots or service kiosks.
4. **Security and Surveillance:** Assists in identifying suspicious behavior by detecting emotions like fear or anger in public spaces.

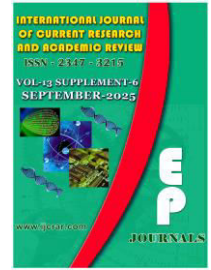


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5. **Entertainment and Gaming:** Creates adaptive experiences by adjusting content based on player emotions.
6. **Automotive Industry:** Monitors driver fatigue or frustration to improve road safety.

Benefits of IBER

1. **Enhanced Human-Computer Interaction:** Makes AI systems more empathetic and natural in responding to users.
2. **Healthcare Support:** Assists clinicians in diagnosis by providing non-intrusive emotional insights.
3. **Personalization:** Tailors learning, shopping, or entertainment experiences based on emotional state.
4. **Automation:** Reduces manual observation in areas like classrooms or hospitals.
5. **Market Research:** Offers businesses deeper insights into consumer reactions to products and advertisements.

Challenges of IBER

- **Variability in Faces:** Differences in age, gender, ethnicity, and facial structures reduce accuracy.
- **Environmental Factors:** Poor lighting, occlusions (glasses, masks), and image quality affect recognition.
- **Cultural Differences:** Expressions of emotions vary across cultures, challenging universality.
- **Privacy Concerns:** Continuous monitoring of emotions raises ethical issues around consent and misuse.
- **Real-Time Processing:** Achieving high accuracy with low computational cost remains a technical barrier.

Conclusion

Image-based emotion recognition systems (IBER) represent a significant advancement in Artificial Intelligence, enabling machines to interpret human emotions through facial expressions and visual cues. By bridging the gap between human emotional intelligence and machine processing, these systems are transforming human-computer interaction, making it



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more natural, intuitive, and context-aware. Their applications are wide-ranging, extending from healthcare, where they assist in mental health monitoring and patient care, to education, where they support adaptive e-learning platforms that respond to students' emotional states. In addition, industries such as customer service, entertainment, automotive, and security are increasingly adopting IBER to improve decision-making, personalize experiences, and enhance safety.

Despite their growing importance, several challenges must be overcome for IBER systems to reach their full potential. Issues such as variations in facial features across populations, differences in cultural expression, environmental conditions like lighting and occlusion, and significant privacy concerns continue to limit accuracy and acceptance. Moreover, achieving real-time performance without compromising reliability remains a key research goal.

With ongoing advancements in deep learning, affective computing, and ethical AI, future IBER systems are expected to be more robust, fair, and inclusive. By addressing these challenges, they can evolve into indispensable tools across multiple domains of everyday life.

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Full Length Article

IJCRAR/FL/22

Architecture and Advanced Techinque of Deep Learning

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Abstract

Deep Learning, a subfield of Machine Learning, focuses on multi-layered neural networks capable of automatically extracting hierarchical features from raw data. Unlike traditional algorithms that rely on manual feature engineering, deep learning architectures such as Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Transformer models learn complex patterns directly from data. With advancements in computational power and large-scale datasets, these models have achieved breakthroughs in computer vision, natural language processing, healthcare, and autonomous systems. This paper explores the architecture of deep learning models, discusses advanced training techniques such as transfer learning, generative models, attention mechanisms, and reinforcement learning, and analyzes their applications and challenges.

Keywords: Deep Learning, Neural Networks, CNN, RNN, Transformer, Transfer Learning, Generative Models, Attention Mechanism, Reinforcement Learning

Introduction

Deep Learning is an advanced domain of Machine Learning that draws inspiration from the structure and functioning of the human brain. At its foundation, deep learning utilizes Artificial Neural Networks (ANNs) composed of multiple hidden layers that progressively process information. This hierarchical representation enables machines to recognize and interpret complex patterns such as images, speech, and text with remarkable accuracy. The rapid



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growth of deep learning has been fueled by the availability of large-scale datasets, high-performance GPUs, and powerful frameworks like TensorFlow and PyTorch, which make model development and training more efficient.

The architecture of deep learning comprises specialized models designed for particular tasks. Convolutional Neural Networks (CNNs) are widely used for image classification and object detection, while Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks excel in analyzing sequential data such as speech and time series. In the field of natural language processing, Transformer-based architectures have become dominant, offering superior scalability and contextual understanding. Recent advancements also include techniques such as attention mechanisms, transfer learning, and Generative Adversarial Networks (GANs), which significantly enhance performance and broaden the applications of deep learning. Despite these achievements, challenges such as computational cost, data dependency, and limited interpretability remain critical areas of ongoing research.

Literature Review

The foundations of deep learning were laid by McCulloch and Pitts (1943), who introduced the concept of artificial neurons. Rosenblatt's Perceptron (1958) marked the first neural network model, while Rumelhart *et al.*, (1986) popularized backpropagation for training multilayer networks.

LeCun *et al.*, (1998) pioneered CNNs for digit recognition, revolutionizing image processing. Later, Hochreiter and Schmidhuber (1997) proposed LSTMs, solving the vanishing gradient problem in sequential data. Recently, Vaswani *et al.*, (2017) introduced the Transformer architecture with attention mechanisms, enabling breakthroughs in natural language processing, including models like BERT and GPT.

Advanced techniques such as GANs (Goodfellow *et al.*, 2014) brought new possibilities in image generation, while Hinton *et al.*, (2012) demonstrated deep learning's power in ImageNet competitions. Current research focuses on improving interpretability (XAI), efficiency, and fairness in large-scale models.



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Architecture of Deep Learning

Artificial Neural Networks (ANNs)

Basic building blocks of deep learning, consisting of input, hidden, and output layers. Used for regression and classification tasks.

Convolutional Neural Networks (CNNs)

Specialized for image and video analysis. They use convolutional layers to automatically extract spatial features like edges, textures, and shapes.

Recurrent Neural Networks (RNNs) & LSTMs

Designed for sequential data such as text, speech, and time series. LSTMs solve long-term dependency issues by using memory cells.

Transformer Models

State-of-the-art architecture for NLP and beyond. They use self-attention to capture contextual relationships across sequences, outperforming RNNs in scalability and accuracy.

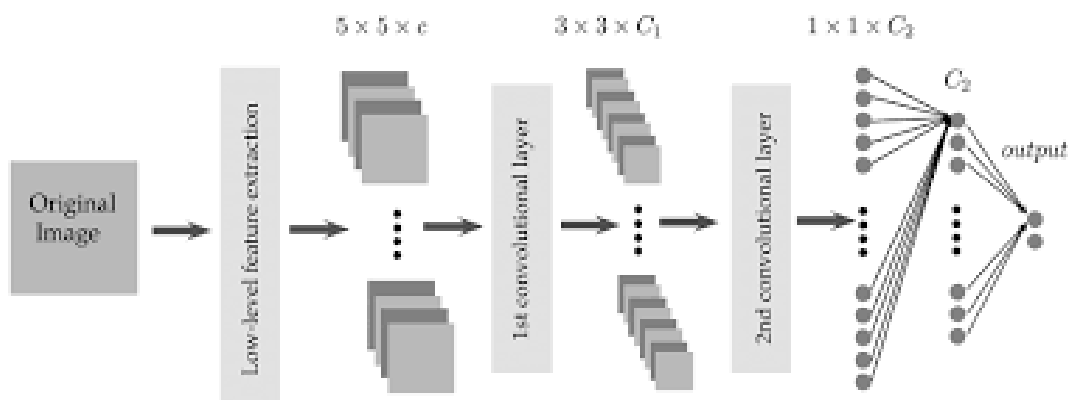


Fig 22.1

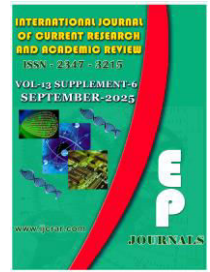


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Advanced Techniques

Transfer Learning

Reusing pre-trained models on large datasets for new tasks, reducing training time and improving performance.

Generative Adversarial Networks (GANs)

Two competing networks (generator and discriminator) that can create realistic data such as images, audio, and video.

Attention Mechanisms

Allow models to focus on important parts of input sequences, improving accuracy in translation, speech recognition, and summarization.

Reinforcement Learning with Deep Networks

Combines deep learning with reinforcement learning to enable agents to make sequential decisions, as in AlphaGo and autonomous driving.

Pros and Cons Deep Learning

Advantages of Deep learning

- High accuracy in tasks like vision and language.
- Eliminates need for manual feature engineering.
- Handles large and complex datasets effectively.

Disadvantages of Deep learning

- Requires massive amounts of data and computing power.
- Acts as a "black box" with limited interpretability.
- Training is time-consuming and costly.



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Conclusion

Deep Learning has transformed artificial intelligence by introducing architectures capable of handling complex and large-scale data. Advanced models like CNNs, RNNs, and Transformers, along with techniques such as transfer learning, GANs, and reinforcement learning, have expanded its applications across industries. Despite challenges related to transparency, cost, and data requirements, ongoing research in Explainable AI and efficient training methods continues to improve its reliability. The future of deep learning lies in creating more interpretable, ethical, and energy-efficient models that strengthen human-AI collaboration.

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Full Length Article

IJCRAR/FL/23

Face Anonymization and Deepfake Forensics

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Abstract

With the increasing proliferation of facial recognition systems and deepfake technologies, privacy protection and media authenticity have become critical challenges in modern surveillance systems. This research explores two interconnected areas: facialde-identification and deepfake detection, both crucial to maintaining ethical standards in video-based surveillance. We investigate reversible and irreversible face-blurring techniques powered by Generative Adversarial Networks (GANs), which allow for identity protection while retaining contextual integrity. Simultaneously, we explore deepfake detection using spatio-temporal feature extraction methods, which analyze both frame-level appearance and motion consistency to differentiate between real and manipulated videos. The paper presents an overview of current methodologies, evaluates their efficacy, and highlights open challenges and limitations in deploying these systems in real-world scenarios.

Keywords: deepfakes, Surveillance technologies, privacy preservation

Introduction

Surveillance technologies have become ubiquitous in public and private spaces, raising concerns about privacy and security. Facial recognition, while useful for law enforcement and access control, poses significant ethical concerns regarding consent and data misuse. Moreover, the rise of deepfakes—AI-generated synthetic videos that convincingly alter identities or speech—has created a parallel threat to information integrity.

This dual concern requires robust systems for privacy preservation and deepfake detection. Facial de-identification aims to obscure personal identity in video feeds without



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losing contextual relevance. On the other hand, deepfake detection seeks to distinguish manipulated content from authentic footage using machine learning techniques. This paper examines the interplay between these two domains, focusing on recent advances using GANs and spatio-temporal modeling.

Objectives

This research aims to:

- Examine current techniques for facial de-identification using GANs.
- Explore spatio-temporal features for deepfake detection.
- Evaluate the performance and limitations of state-of-the-art models.
- Propose an integrated framework for privacy and authenticity in video surveillance.
- Discuss real-world implications, challenges, and ethical considerations.

Literature Review

Facial De-identification

Facial de-identification techniques traditionally used blurring or pixelation. However, these methods are easily reversible and degrade the image quality. Modern approaches use GANs such as k-Same-Net or Fawkes, which generate synthetic facial representations while preserving emotions and expressions. These can be irreversible (permanent anonymization) or reversible (de-identification can be undone with a private key or model).

Deepfake Detection

Deepfake detection has evolved from static image analysis to dynamic video analysis. Spatio-temporal methods analyze both visual artifacts (e.g., inconsistent lighting, blurred edges) and temporal cues (e.g., unnatural blinking, head motion).

Methodology

This research employs a dual-pipeline approach: one for facial de-identification and the other for deepfake detection, both applied to video streams. Each component is designed to either protect individual privacy or verify the authenticity of visual data.



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Facial De-identification Pipeline

We adopt a GAN-based reversible or irreversible de-identification method that preserves facial expressions and head pose while removing identifiable facial features.

Steps

1. Face Detection using MTCNN or Dlib to localize faces in each frame.
2. Feature Extraction with models like FaceNet or ArcFace.
3. Identity Masking using conditional GANs (e.g., DeepPrivacy, k-Same-Net) to synthesize non-identifiable faces.
4. Reintegration of the generated face using seamless blending.
5. Video Reconstruction using OpenCV or FFmpeg.

Variants

- *Reversible*: Face encoded via a secure encoder-decoder mechanism.
- *Irreversible*: Synthesized face fully anonymized with no reversible mapping.

Deepfake Detection Pipeline

We use a spatio-temporal architecture that extracts both appearance and motion features.

Steps

1. **Preprocessing**: Frame sampling and normalization.
2. **Spatial Feature Extraction** using CNNs (e.g., ResNet50, EfficientNet).
3. **Temporal Modeling** using LSTM, GRU, or 3D CNNs (e.g., I3D, C3D).
4. **Fusion Architecture** (optional): Combines RGB and optical flow inputs.
5. **Classification**: Binary classification using softmax or sigmoid activation.
6. **Datasets**: FaceForensics++, Celeb-DF, and DFDC are used for benchmarking.



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Benefits

- **Privacy Compliance:** Enables adherence to privacy laws such as GDPR.
- **Security Enhancement:** Identifies media manipulation early.
- **Context Retention:** Maintains emotions and actions even after de-identification.
- **Scalable Design:** Models can be optimized for cloud or edge devices.

Challenges

- **High Computational Costs:** GANs and LSTMs require significant resources.
- **Limited Generalization:** Most models struggle with unseen faces or fake generation techniques.
- **False Positives in Detection:** Minor anomalies may trigger incorrect flags.
- **User Trust:** Balancing security and transparency remains difficult.

Limitations

- Current de-identification can be bypassed with advanced facial recognition systems.
- Spatio-temporal models underperform on low-res or compressed videos.
- Lack of high-quality, diverse datasets restricts robustness.
- Real-time application is still limited in many real-world surveillance settings.

Conclusion

Facial de-identification and deepfake detection are two crucial components for building ethical and secure video surveillance systems. This research explored modern GAN-based approaches for anonymization and spatio-temporal models for deepfake detection. While current tools show promise, real-world deployment still faces hurdles related to computational cost, generalization, and ethical trade-offs. Future work should explore lightweight models, cross-domain generalization, and hybrid systems that offer both privacy and security without compromising performance.



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Full Length Article

IJCRAR/FL/24

AI-Neuroeducation Integration in Higher Education

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Abstract

Artificial Intelligence (AI) and neuroeducation are increasingly recognized as transformative forces in higher education, offering new pathways for personalized learning, adaptive assessment, and neuroscience-informed pedagogy. To investigate the intersection of AI and neuroeducation in enhancing teaching and learning outcomes, this work synthesizes insights from recent literature, including empirical research, systematic reviews, and exploratory faculty surveys. We review applications of AI in computer science education, the role of neuroscience insights in pedagogy, and the integration of cognitive load monitoring and neuroadaptive systems. By analysing challenges such as ethical risks, accessibility, and teacher-student dynamics, the paper proposes a framework for responsible AI-enabled, neuroscience-informed pedagogy. Our findings suggest that AI-driven tools, combined with neuroeducation strategies, hold significant promise for enhancing learning engagement, retention, and inclusivity, require robust ethical safeguards and faculty training to ensure meaningful adoption in higher education.

Keywords: Neuroeducation, Educational Neuroscience, Artificial Intelligence

Introduction

Higher education is undergoing rapid transformation with the integration of Artificial Intelligence (AI) and Educational Neuroscience (Neuroeducation). AI technologies, such as adaptive learning systems, natural language processing, and intelligent tutoring, mirror human cognitive processes and reshape traditional teaching paradigms. Neuroeducation integrates



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neuroscience with pedagogy, highlighting the significance of emotion, memory, and engagement in durable learning. Despite progress, a gap persists between theoretical advances and their actual implementation in classrooms. Faculty often acknowledge the value of neuroscience but struggle to translate it into teaching practice, while AI adoption is hindered by ethical and practical challenges. This paper explores how AI and neuroeducation can be combined to address these challenges, offering a conceptual framework for evidence-based, adaptive teaching in higher education.

Literature review

Ashish Shiwlani *et al.*, (2024) [1] conducted a systematic review of 35 studies on AI and neuroeducation, showing how adaptive learning platforms, neurofeedback systems, gamified environments, and immersive technologies like VR/AR enhance personalization, engagement, and long-term retention through alignment with principles including neuroplasticity and memory formation. While highlighting machine learning's ability to reveal complex patterns, the review also notes risks like overfitting, model opacity, and ethical concerns. The authors illustrate these issues with neuroscience examples and propose a roadmap with best practices and future directions to guide responsible AI adoption in research and education.

Yashpal D. Netragaonkar (2022) [2] explores the role of artificial intelligence in higher education, presenting AI as a technology that mirrors human cognitive functions such as reasoning, learning, decision-making, and problem-solving, with strong potential to transform teaching and learning. Based on secondary sources including academic literature, expert views, and institutional reports, the paper aims to clarify the concept of AI, analyze its applications in higher education, and highlight its significance for academic institutions. The author argues that AI enhances accessibility, efficiency, and innovation through adaptive learning, intelligent assessment, and faster content delivery, positioning it as an integral element in the future of university operations and pedagogy. Xuesong Zhai *et al.*, (2021) [3] analyzed 100 research articles (63 empirical, 37 analytic) published between 2010 and 2020 to examine how AI is used in education, categorizing findings into three layers: development (AI techniques like classification, recommendation, deep learning), application (AI-mediated feedback, reasoning, adaptive learning), and integration (affective computing, immersive learning, gamification). They highlight emerging trends such as IoT, swarm intelligence, and neuroscience, while



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stressing the importance of assessment strategies and addressing challenges like misuse, shifting teacher-student roles, and ethical concerns. The study provides a solid framework for understanding AI's educational impact and calls for closer collaboration between educators and AI engineers. Mohamed Khaleel *et al.*, (2024) [4] provide a comprehensive review of AI's evolution from the Dartmouth Conference and Turing Test to modern advances in deep learning and generative AI, outlining paradigms from reactive machines to aspirational self-aware systems and covering key techniques like machine learning, computer vision, knowledge representation, and optimization. The paper highlights AI's integration across computer science domains such as algorithms, data management, software engineering, HCI, and cybersecurity, while addressing limitations including bias, privacy, job displacement, interpretability, scalability, and human-AI collaboration. Concluding, the authors position AI as both shaped by and driving innovation in computer science, stressing the need for ethical stewardship and interdisciplinary collaboration. Lydia Velázquez-García *et al.*, (2025) [5] reviewed how AI tools—such as intelligent tutoring, adaptive learning, performance prediction, and assessment systems—are improving personalization, engagement, and feedback in computer science education. It identifies 13 key applications while also noting challenges like data privacy, bias, and the need for faculty training. The study concludes that AI holds great potential to transform higher education if implemented thoughtfully and ethically.

Maria Fragkaki *et al.*, (2022)[6] conducted an exploratory mixed-methods study with 60 instructors from five Greek universities to examine perceptions, practices, and training needs in neuroeducation. While faculty recognized the value of neuroscience in areas like emotion, memory, and engagement for effective learning, the study revealed a gap between their theoretical knowledge and teaching practices, along with the persistence of neuromyths. Instructors expressed the need for a deeper understanding of memory mechanisms and training in neuroscience-informed, creative, and authentic assessments to foster engagement, creativity, and critical thinking. The findings highlight the importance of neuroeducation training to better align pedagogy with evidence-based neuroscience

Gkintoni *et al.*, (2025) [7] conducted a systematic review of 103 studies (2014–2024) linking Cognitive Load Theory, Educational Neuroscience, AI, and ML, showing that neuroadaptive systems using EEG, fNIRS, and ML models (CNNs, RNNs, SVMs) can monitor cognitive load in real time and deliver personalized instruction that improves learning outcomes through



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optimized load management, tailored feedback, and multimodal data integration. While highlighting these benefits, the review also underscores key challenges such as ethical concerns, privacy, bias, accessibility, and scalability, concluding that future efforts must focus on inclusive, cost-effective, and ethically grounded implementation for responsible adoption in education.

Methodology

This paper employs a conceptual literature review methodology centered on the integration of Artificial Intelligence and Neuroscience frameworks in higher education. The analysis followed a thematic synthesis model, focusing exclusively on the integration of AI-Neuroscience frameworks. Publications were reviewed, coded, and clustered around three dimensions as in Fig. (1):

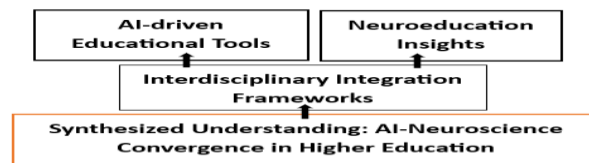


Fig 24.1 Block Diagram of the Proposed System

AI-driven Educational Tools

Artificial Intelligence provides a diverse range of tools that enhance teaching, learning, and administration in higher education. AI-driven educational tools and applications (adaptive learning systems, predictive analytics, cognitive modeling). Adaptive learning systems personalize content delivery by analyzing students' progress and adjusting difficulty levels, while predictive analytics identify at-risk learners and optimize interventions. Cognitive modeling and intelligent tutoring systems replicate aspects of human instruction, offering real-time guidance and feedback. Collectively, these AI applications enable data-driven decision-making, individualized learning pathways, and greater efficiency in managing academic processes.



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Neuroeducation Insights

Neuroeducation insights (cognitive load, brain-based learning, attention, and memory processes). Neuroeducation draws on findings from cognitive neuroscience to inform how the brain learns best. Concepts such as cognitive load theory, attention management, and memory consolidation provide a scientific foundation for designing effective teaching strategies. By understanding how neural mechanisms support learning, educators can align AI-driven tools with brain-based principles, ensuring that technology does not overwhelm learners but instead enhances focus, engagement, and retention. These insights form the bridge between neuroscience and pedagogical practice.

Interdisciplinary Integration Frameworks

The intersection of AI and neuroscience requires frameworks that integrate technological capabilities with cognitive principles as in Fig (2). Such frameworks guide how adaptive algorithms can incorporate brain-based evidence to personalize instruction, reduce extraneous load, and support deeper learning. For example, machine learning systems can be trained to detect patterns of student disengagement while aligning interventions with neuroscience-backed strategies for attention recovery. These integration models not only combine two disciplines but also provide a blueprint for scalable, evidence-based innovation in education. Interdisciplinary integration frameworks that demonstrate how AI can leverage neuroscience principles to enhance teaching and learning outcomes.



Fig 24.2 Conceptual Framework – Integration of AI + Neuroeducation → Adaptive Pedagogy.



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By comparing and synthesizing findings across these dimensions, the review identifies conceptual overlaps, emerging models, and gaps that inform a deeper understanding of AI-neuroscience convergence in higher education.

Discussion

The findings highlight that AI applications such as adaptive feedback, automated grading, intelligent tutoring, and gamified immersive environments enhance both efficiency and engagement in higher education, particularly in computer science, where they foster personalized problem-solving and skill-building. The integration of neuroeducation with AI is enriched by neurobionic adaptive networks for accomplishing real-time cognitive load, and multi-source data, enabling a more custom-made learning experience.

Transformative directions for higher education

The transformative directions are presented in the form of a diagram as in Fig (3).

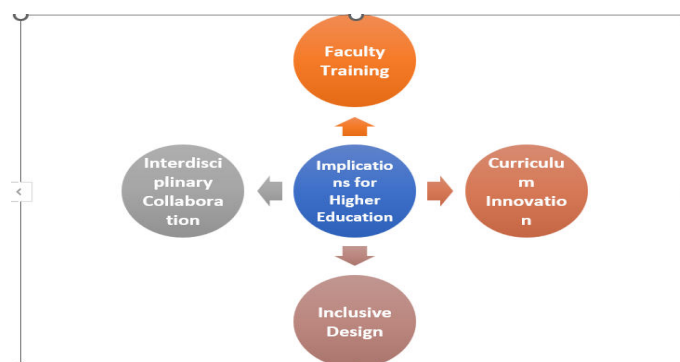


Fig 24.3 Circular wheel

Conclusion

AI and neuroeducation together hold immense potential to revolutionize higher education through adaptive, evidence-based teaching. By aligning AI's computational power

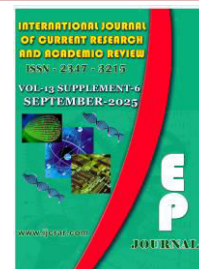


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with neuroscience's insights into learning, institutions can create engaging, personalized, and equitable learning environments. Realizing this potential necessitates addressing ethical, technical, and pedagogical challenges. Future research should prioritize cost-effective, inclusive, and ethically responsible frameworks, fostering collaboration between educators, technologists, and policymakers.

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Full Length Article

IJCRAR/FL/25

Application on Smartcities in IOT

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Abstract

The Internet of Things (IoT) is revolutionizing urban living by connecting devices, sensors, and systems to enable real-time data exchange and intelligent decision-making. In smart cities, IoT applications improve infrastructure, optimize resource usage, and enhance citizens' quality of life. Key areas include smart transportation for traffic management, energy systems for efficient power distribution, waste management through sensor-enabled bins, and water monitoring to prevent leaks and ensure quality. In IoT supports public safety via connected surveillance and emergency response systems. These technologies enable cities to reduce costs, minimize environmental impact, and deliver better services. However, challenges such as high implementation costs, data security, and privacy concerns remain significant. With advancements in AI, 5G, and cloud computing, IoT promises to make cities more sustainable, efficient, and citizen-friendly, transforming urban environments into intelligent ecosystems for the future.

Keywords: IoT, Smart Cities, Smart Transportation, Energy Management, Waste Management, Water Monitoring, Public Safety, Real-Time Data, Sustainability, 5G, Cloud Computing, AI

Introduction

The Internet of Things (IoT) is a cutting-edge technology that connects physical devices, sensors, and systems to the internet, enabling them to collect, share, and analyze data in real time. In the context of smart cities, IoT plays a vital role in addressing the growing challenges of urbanization, such as traffic congestion, energy consumption, waste management, and public safety. By integrating IoT-enabled solutions, cities can enhance operational efficiency, reduce



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costs, and provide a better quality of life for residents. Smart transportation systems, for example, use IoT sensors and GPS devices to monitor traffic flow and optimize routes, reducing travel time and fuel consumption. Similarly, IoT-powered energy grids allow for efficient electricity distribution and smart lighting, minimizing energy wastage. Waste management systems leverage sensors to track bin levels and improve collection schedules, while water monitoring systems help detect leaks and maintain water quality. Additionally, IoT enhances security through connected surveillance cameras and emergency response networks. Despite its numerous benefits, IoT implementation in smart cities faces challenges such as data privacy, cybersecurity risks, and high infrastructure costs. However, with advancements in artificial intelligence (AI), 5G connectivity, and cloud computing, IoT continues to pave the way for sustainable, intelligent urban ecosystems.

Literature Review

The Internet of Things (IoT) has emerged as a key enabler in the development of smart cities, integrating physical and digital infrastructure for improved urban management. Atzori, Iera, and Morabito (2010) define IoT as a paradigm where everyday objects are equipped with sensors and communication capabilities to interact and share data. This concept provides the foundation for smart city applications that ensure efficient use of resources and better quality of services.

Gubbi *et al.*, (2013) emphasize that IoT enables real-time monitoring and decision-making, which is crucial for areas like transportation, energy management, and environmental monitoring. Similarly, Zanella *et al.*, (2014) discuss how IoT facilitates smart solutions, such as traffic control systems, waste management, and smart grids, to address the challenges of rapid urbanization.

Al-Fuqaha *et al.*, (2015) provide a comprehensive overview of IoT architecture, communication protocols, and applications, highlighting its role in improving sustainability and enhancing citizen experiences. Recent research also points to challenges such as security risks, data privacy issues, and scalability concerns, which require innovative solutions through AI, edge computing, and blockchain technologies.



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Overall, literature shows that IoT is a cornerstone of smart city development, offering both opportunities and challenges for future urban ecosystems.

Tools for IOT

IoT implementation in smart cities relies on a variety of tools, platforms, and technologies that enable data collection, communication, analysis, and visualization. These tools help manage IoT devices, ensure interoperability, and provide real-time insights for decision-making.

AWS IoT Core

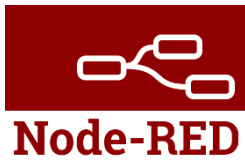
Amazon Web Services (AWS) IoT Core provides a cloud platform for securely connecting IoT devices, managing data, and enabling real-time analytics. It supports scalability for large smart city networks.

Node-RED

Node-RED is a flow-based development tool for visual programming. It is commonly used for integrating IoT devices, APIs, and online services, simplifying smart city application development.

Google Cloud IoT

Google Cloud IoT offers a suite of managed services for device connectivity, data storage, and analytics, helping cities build intelligent, connected ecosystems.

		
Fig 25.1	Fig 25.2	Fig 25.3



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Purpose of IOT

The primary purpose of the Internet of Things (IoT) is to create an interconnected ecosystem of devices that can collect, exchange, and analyze data to enable automation and intelligent decision-making. In the context of smart cities, IoT serves the following key purposes:

Enhancing Urban Infrastructure

IoT enables real-time monitoring and control of critical infrastructure such as transportation systems, energy grids, and water supply networks, improving operational efficiency and reducing downtime.

Resource Optimization

By gathering data from sensors and devices, IoT helps optimize resource usage, including electricity, water, and fuel, leading to cost savings and environmental sustainability.

Improving Quality of Life

IoT-powered smart services such as intelligent traffic systems, smart lighting, and connected healthcare enhance the daily living standards of citizens by providing convenience and safety.

Data-Driven Decision Making

IoT collects large volumes of data from multiple sources, enabling authorities to make informed decisions for city planning, emergency response, and service improvements.

Automation of Services

IoT facilitates automation in areas like waste collection, traffic control, and energy management, reducing the need for manual intervention and improving efficiency.



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Pros and Cons of IOT

Advantages of IOT

- **Automation and Efficiency** – IoT enables automation of routine tasks, reducing human effort and improving efficiency in urban services like traffic control and waste management.
- **Real-Time Monitoring** – Provides real-time data on infrastructure, energy usage, and environmental conditions, helping authorities make informed decisions.
- **Resource Optimization** – Helps optimize energy, water, and other resources, reducing operational costs and promoting sustainability.
- **Improved Quality of Life** – Enhances citizen services through smart transportation, healthcare, and security systems.

Disadvantages of IOT

- **Security Risks** – IoT devices are vulnerable to cyber-attacks, leading to data breaches and privacy concerns.
- **High Implementation Cost** – Setting up IoT infrastructure and maintaining devices require significant investment.
- **Data Overload** – Managing and analyzing massive volumes of IoT-generated data is complex and resource-intensive.
- **Interoperability Issues** – Lack of standardized protocols makes integration of different IoT systems challenging.

Conclusion

The Internet of Things (IoT) has become a key driver in the development of smart cities, enabling real-time data collection, automation, and intelligent decision-making. By integrating IoT solutions into urban infrastructure, cities can optimize resources, improve efficiency, and enhance the overall quality of life for citizens. Applications such as smart transportation, energy management, waste control, water monitoring, and public safety illustrate the transformative potential of IoT in creating sustainable urban environments.



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However, despite these benefits, challenges such as high implementation costs, data security, privacy concerns, and interoperability issues remain significant barriers to widespread adoption. Addressing these issues through advanced technologies like AI, 5G, cloud computing, and blockchain will be essential for future growth. As cities continue to evolve, IoT will play an increasingly critical role in shaping intelligent, sustainable, and connected urban ecosystems for the future.

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Full Length Article

IJCRAR/FL/26

Secure Data Sharing and Collaboration in Cloud-Based Environments

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Abstract

The rapid adoption of cloud computing has revolutionized data storage and collaboration, enabling organizations to share and access data seamlessly across distributed environments. However, the cloud's open nature poses significant security and privacy challenges. This paper explores current methods, tools, and efficient strategies for secure data sharing and collaboration in cloud-based environments. We analyze existing literature, discuss prevalent limitations and challenges, and highlight emerging functionalities and technologies that enhance secure collaboration. Our findings emphasize the importance of encryption, access control, and trust management mechanisms to protect sensitive data while ensuring smooth collaboration.

Keywords: Data storage, Collaboration, Distributed environments, Security, Privacy, Current methods, Tools, Efficient strategies, Secure data sharing, Limitations, Challenges, Emerging functionalities, Technologies, Encryption, Access control, Trust management

Introduction

Cloud computing has become an indispensable technology, offering scalable storage, computation, and collaboration services. Organizations increasingly rely on cloud platforms to share data and collaborate in real time across geographical boundaries. Despite its benefits, cloud environments introduce security risks including data breaches, unauthorized access, and loss of data integrity. Ensuring secure data sharing while maintaining usability and



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collaboration efficiency is a critical concern. This paper aims to investigate existing secure data sharing techniques in cloud environments, identify challenges, and propose efficient methodologies to address them.

Literature Review

Several studies focus on securing data in cloud environments. Traditional methods include encryption schemes such as symmetric and asymmetric cryptography, attribute-based encryption (ABE), and homomorphic encryption to protect data confidentiality. Access control models, including Role-Based Access Control (RBAC) and Attribute-Based Access Control (ABAC), regulate user permissions. Trust management and authentication mechanisms enhance security in collaborative settings.

Recent advancements include blockchain technology for decentralized trust, secure multi-party computation (SMPC) for privacy-preserving data sharing, and the integration of artificial intelligence to detect anomalous activities. Despite progress, challenges remain in balancing security, usability, and computational overhead.

Methodology

This research adopts a and qualitative experimental methodology to analyze, design, and evaluate secure data sharing and collaboration mechanisms within cloud-based environments. The study is structured into four primary phases: literature review, requirements analysis, and implementation of designa prototype system, and evaluation through testing and simulation.

1. Literature Review and Problem Identification
2. System Architecture Design
3. Threat Modeling and Security Analysis
4. Implementation and Tooling
5. Evaluation Metrics and Experimental Setup
6. Limitations and Assumptions



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This study assumes

- Trust in the security middleware component.
- A semi-honest cloud provider (not actively malicious, but curious).
- Users operate from secure client devices.
- The system currently does not address side-channel attacks or full malicious insider threats.

Limitations

- **Performance Overhead:** Encryption and decryption processes increase computational load and latency.
- **Scalability Issues:** Managing access controls and keys for large user groups can be complex.
- **Usability Concerns:** Complex security measures may hinder seamless collaboration.
- **Trust Management:** Difficulties in establishing trust among multiple, potentially unknown collaborators.
- **Data Integrity Risks:** Ensuring data is unaltered during sharing and collaboration is challenging.

Challenges

- Ensuring confidentiality without compromising collaboration speed.
- Implementing fine-grained access control to prevent unauthorized data exposure.
- Managing key distribution and revocation in dynamic user environments.
- Maintaining data integrity and auditability in multi-user cloud environments.
- Balancing security and usability to encourage adoption.
- Addressing compliance and regulatory requirements for data privacy.

Functionlities for Sucure Cloud Data Sharing

- **Data Encryption:** Both at rest and in transit.



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- **Access Control Mechanisms:** RBAC, ABAC, and policy-based controls.
- **Authentication and Authorization:** Multi-factor authentication (MFA) and federated identity management.
- **Data Auditing and Logging:** Tracking access and modifications.
- **Secure Collaboration Tools:** Document sharing platforms with integrated security.

Tools and Technologies

- **Encryption Libraries:** OpenSSL, AWS KMS, Azure Key Vault.
- **Access Management:** OAuth, OpenID Connect, LDAP.
- **Collaboration Platforms:** Microsoft 365, Google Workspace with built-in security.
- **Blockchain Frameworks:** Hyperledger, Ethereum for decentralized trust.
- **Secure File Sharing Tools:** Tresorit, SpiderOak.
- **Data Loss Prevention (DLP) Solutions:** Symantec DLP, McAfee DLP.

Efficient methods for sharing secure data

- **Attribute-Based Encryption (ABE):** Enables fine-grained access control based on user attributes.
- **Proxy Re-Encryption:** Allows data sharing without exposing plaintext keys.
- **Homomorphic Encryption:** Permits computation on encrypted data without decryption.
- **Secure Multi-Party Computation (SMPC):** Enables collaborative computations while keeping data private.
- **Hybrid Encryption Models:** Combining symmetric and asymmetric encryption to optimize performance.

Conclusion

Secure data sharing and collaboration in cloud environments is essential yet complex due to the competing demands of security, privacy, and usability. While significant advancements have been made in encryption, access control, and trust management, challenges such as scalability, usability, and compliance remain. Efficient methods like attribute-based encryption and proxy re-encryption offer promising solutions for secure, flexible collaboration. Future



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research should focus on integrating these techniques seamlessly into cloud platforms, enhancing automation, and improving user experience to foster secure and effective cloud-based collaboration.

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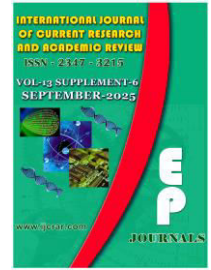


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Full Length Article

IJCRAR/FL/27

FN-Guard: A Multimodal and Explainable Framework for Fake News Detection

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Abstract

Fake news on social media has become a serious problem because it threatens democracy, public health, and people's trust in information. Most current detection methods look at either the text, the images, or the way a story spreads online, but they often fail when misinformation combines multiple types of content or is shared in a coordinated way. To deal with this, we developed FN-Guard, a new system that brings together signals from text, images, and sharing patterns using advanced machine learning and graph analysis. What makes FN-Guard different is that it doesn't just give a prediction, it also explains why it flagged something as fake, so users can better trust the system. We tested FN-Guard on well-known datasets from Twitter, PHEME, and Weibo, and it consistently performed better than other leading methods, improving accuracy (F1-score) by up to 7%. This shows that combining multiple types of information with explainable AI is a powerful way to tackle the spread of misinformation.

Keywords: Fake News Detection, Multimodal Learning, Explainable AI, Deep Learning, Social Media

Introduction

The explosive growth of social media has transformed how information spreads, but it has also made it easier for misinformation and fake news to circulate. Fake news refers to deliberately false or misleading content that mimics real news. Its impact can be serious from swaying election results to weakening public trust in healthcare advice during crises like the



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COVID-19 pandemic. Early attempts to detect fake news focused mainly on text, looking for clues such as writing style, tone, or unusual emotional patterns. With the rise of machine learning, more advanced models including CNNs, RNNs, and modern Transformers like BERT and RoBERTa, have greatly improved text-based detection. However, fake news now often appears in multimodal forms, where carefully crafted text is paired with doctored images, videos, or memes to make the deception more convincing. At the same time, misinformation frequently spreads in coordinated ways, where analyzing how content is shared across a network can reveal valuable evidence of suspicious activity. Despite these advances, most current solutions struggle with two key problems.

First, many methods are unimodal, focusing only on text or only on images, which limits their effectiveness against more complex cases. Second, deep learning systems often act as “black boxes”, making accurate predictions but giving little insight into *why* something is flagged as fake, which reduces user trust. To overcome these issues, this paper introduces FN-Guard, a framework that combines information from text, visuals, and propagation patterns, while also providing explanations for its decisions. This makes the system both more reliable and more interpretable for users.

Related Work

Early fake news detection methods looked at simple things like word counts and sentiment, but these missed the bigger picture, so researchers moved on to deep learning and transformer models like BERT and RoBERTa, which did a better job of understanding context but could still miss cases where the language sounds true but is actually misleading. Later, people started analyzing images using CNNs and Vision Transformers to catch fake or manipulated visuals, though checking images alone often wasn't enough if you ignored the text or situation they appeared in. Others focused on how news spreads online, using graph-based models like GNNs and GATs to show that fake news tends to travel faster and reach more people than real news, giving clues that go beyond the content itself. The latest and strongest approaches combine text, images, and how stories spread for a fuller picture yet these systems, like MVAN and DualGNN, often don't explain their decisions in ways people can understand, which is why FN-Guard was designed to bring everything together and add clear, trustworthy explanations.



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Proposed Methodology

FN-Guard has three main parts: it uses RoBERTa to understand the context of news articles, a Vision Transformer to spot manipulated or irrelevant images, and a Graph Attention Network to analyze how news spreads across social networks. These components work together through a cross-modal attention system that focuses on the most important information from each source.

To help people trust and understand its decisions, FN-Guard also provides explainability tools like heatmaps that highlight suspicious words, saliency maps showing potentially fake parts of images, and visual graphs that reveal unusual patterns in how news travels making it easier for analysts and organizations to interpret and rely on its results.

Experimental Setup

Datasets

FN-Guard is evaluated on three popular datasets to test its performance across different types of fake news. Twitter15 contains 1,490 multimodal stories combining text and images. PHEME is a rumor dataset focusing on text and how information spreads through propagation. Weibo is a Chinese microblog dataset that includes text, images, and network data, offering a diverse and comprehensive benchmark for multimodal fake news detection.

Baselines

FN-Guard detects fake news by combining three modules: RoBERTa for text, Vision Transformer for images, and Graph Attention Network for news propagation, all integrated with cross-modal attention to focus on key features. It provides explainable AI tools like heatmaps, saliency maps, and graph visualizations to make its decisions transparent. Evaluated on Twitter15, PHEME, and Weibo datasets, FN-Guard is compared against RoBERTa (text-only), MVAN (multimodal), and DualGNN (graph + text), showing improved performance by combining multiple data sources with explainability. Key metrics like accuracy, precision, recall, F1-score, and AUC-ROC measure its effectiveness.



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Metrics

For evaluating FN-Guard, a fake news detection system, several key metrics are used to measure its effectiveness. Accuracy shows the overall correctness by calculating how often the system correctly identifies news as real or fake, but it can be misleading if the dataset is unbalanced. Precision measures how many of the news items flagged as fake are truly fake, which helps prevent real news from being wrongly labeled and maintains user trust. Recall (or sensitivity) tracks how many actual fake news articles are correctly detected, minimizing fake news that slips through unnoticed.

The F1-Score combines precision and recall into a single measure, balancing false positives and false negatives, which is crucial because both types of errors can have serious consequences. Lastly, the Area Under the ROC Curve (AUC-ROC) assesses how well the model distinguishes fake from real news across different thresholds, showing its overall ability to separate the two. These metrics rely on counts of true positives (correctly identified fake news), true negatives (correctly identified real news), false positives (real news wrongly flagged), and false negatives (fake news missed by the system).

The formulas look like this:

Accuracy = (True Positives + True Negatives) / Total cases

Precision = True Positives / (True Positives + False Positives)

Recall = True Positives / (True Positives + False Negatives)

F1-Score = $2 \times (\text{Precision} \times \text{Recall}) / (\text{Precision} + \text{Recall})$

In fake news detection, F1-score is especially emphasized since it balances the cost of missing fake news and wrongly flagging legitimate news. Using these metrics together ensures FN-Guard strikes the right balance between catching as much false information as possible without creating unnecessary distrust by mislabeling truthful news.



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Results and Discussion

FN-Guard consistently delivers improvements of 4 to 7 percent over well-established baseline models, demonstrating the clear advantage of integrating multiple types of data : text, images, and propagation patterns, into one unified system. This multimodal approach allows FN-Guard to capture subtle cues that other models might miss. For example, in some cases, the text and accompanying images may both appear genuine and consistent on the surface, making the news seem trustworthy. However, FN-Guard goes beyond content analysis by examining how the news spreads across social networks. Its ability to detect unusual or suspicious propagation patterns helps reveal underlying deception that isn't obvious from the content alone. This deeper insight makes FN-Guard particularly effective at catching sophisticated fake news that tries to slip through traditional detection methods. These findings highlight several important insights about effective fake news detection using multimodal approaches like FN-Guard. First, multimodality truly matters. By combining signals from text, images, and network propagation patterns, the system leverages complementary strengths that each modality offers. Text analysis captures linguistic nuance and semantic context, image analysis detects manipulation or irrelevant visuals, and network analysis uncovers suspicious patterns in how information spreads. When these elements are integrated within a unified framework, they provide a richer and more accurate understanding of whether news is real or fake. This holistic view helps the system detect sophisticated deception attempts that might slip past models relying on any single data type. Second, interpretability plays a critical role in building user trust and making fake news detection practical. Models that operate as black boxes may deliver accurate results but fail to inspire confidence among key stakeholders such as journalists, regulators, and fact-checkers. FN-Guard addresses this by incorporating explainable AI tools that provide clear visualizations—like attention heatmaps for text, saliency maps for images, and propagation graphs—that help users understand why a particular news piece is flagged as suspicious. These explanations make it possible for analysts to validate and act on the system's predictions with greater confidence, supporting real-world decisions and interventions against misinformation. Despite these advancements, important challenges remain. Scaling up fake news detection systems to work in real-time on the vast streams of online content presents technical difficulties, including processing speed, data volume, and maintaining accuracy. Additionally, the threat landscape is continuously evolving with increasingly sophisticated adversarial attacks, such as deepfakes and synthetic news generated by advanced AI techniques.



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These evolving threats require ongoing research to develop more robust defenses, including methods to detect manipulated media and false narratives crafted to evade current detection mechanisms. FN-Guard underscores the importance of leveraging multimodal data and explainability to enhance fake news detection. At the same time, it calls attention to future research directions necessary to overcome scalability issues and emerging adversarial challenges, ensuring these tools remain effective and trustworthy in the fight against misinformation.

Conclusion

This paper presented FN-Guard, a multimodal and explainable framework designed to improve fake news detection by integrating textual, visual, and propagation signals. FN-Guard not only boosts detection accuracy but also enhances transparency through explainable AI features, making its predictions more understandable and trustworthy. Looking ahead, future work will focus on expanding FN-Guard's capabilities to support multilingual and cross-platform detection, enabling it to handle diverse languages and various social media ecosystems. Additionally, developing real-time detection pipelines will be a priority to keep pace with the fast flow of online information. Another important direction is building models that are robust against adversarial attacks, particularly to defend against increasingly sophisticated synthetic content like deepfakes and AI-generated misinformation. These enhancements will help FN-Guard remain effective and reliable in the evolving landscape of fake news.

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Full Length Article

IJCRAR/FL/28

Internet of Things (IOT) Fusion with Cloud Computing: Current Research and Future Direction

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Abstract

The integration of Internet of Things (IoT) with cloud computing has emerged as a transformative approach for enabling scalable, real-time, and intelligent services across various domains, including smart cities, healthcare, manufacturing, and transportation. This paper presents a comprehensive review of the current state of IoT-cloud fusion, outlining the dominant architectural models such as cloud-centric, edge-assisted, and hybrid computing paradigms. The paper also explores the challenges of latency, security, interoperability, and energy efficiency, which remain critical in large-scale IoT-cloud deployments.

Keywords: Internet of Things (IoT), Cloud Computing, Edge Computing, Fog Computing, Server less Architecture, Data Analytics, Smart Systems, Security, Scalability, Future Trends

Introduction

The internet of things (IoT) represents a revolutionary concept that has become a part of modern society and is generating tremendous enthusiasm among both the business and academic communities. IoT, as the next-generation technology, has enormous ramifications for many industries.

A system that is embedded with a combination of software, electronic components, actuators, sensors, detectors, and wireless connectivity, which enables them to gather data from these objects can be defined as the —IoT. An IoT system has the following prominent characteristics :

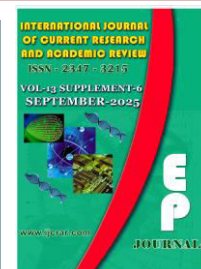


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- IoT is a technological advancement that enables objects to be connected to the internet via wired or wireless networks so that they can communicate with one another.
- A variety of wireless sensor networks are available for IoT devices, including near-field communication (NFC), Zig bee, radio frequency identification (RFID), Bluetooth, and Wi-Fi.
- The sensors can be connected to various technologies, including long-term evolution (LTE), general packet radio service (GPRS), third generation of mobile telephony (3G), and global system for mobile communication (GSM).
- The efficiency of an IoT system is largely determined by three primary components, each of which is crucial to its operation.
 - Perception
 - Middle-ware (Edge, Fog, and Cloud)
 - Application

Background

A brief introduction to some of the most important aspects and terminology used throughout this study is provided in this section. This section is intended to help the reader understand and better comprehend the information that is presented in each section of the paper.

Internet of things (IoT)

Kevin Ashton, a British technology pioneer, formed the phrase "IoT" in 1999 to represent a system in which physical artifacts are connected to the internet using sensors. A "thing" can refer to any physical entity on the surface of the earth, whether it is a communication device or not.

Three-layered architecture of IoT

IoT architecture comprises mainly three layers, namely perception layer, middleware layer, and application layer, as demonstrated in Figure 1. The middle layer of this architecture exists on the edge, fog, and cloud computing.



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Perception layer

Perception layer senses data from the surrounding via actuators and sensors. It identifies, gathers, and processes data and sends it to the network layer. It detects other physical parameter in the physical environment or recognize intelligent objects. **Middleware**

As the 'processing layer', the middleware is responsible for the analysis, processing, and storage of a large amount of data obtained from the perception layer

Application layer

It is the responsibility of this layer to provide specialized application services to the client. As a result, it includes a variety of applications, including air quality monitoring, smart buildings, precision farming, intelligent cities, and innovative health care, as well as data integrity, authenticity, and security.

Cloud computing

During the last few decades, cloud computing has taken on several definitions. As per National Institute of Standards and Technology (NIST): "Cloud computing is a service delivery model that facilitates easy, on-demand access to a shared pool of flexible computing resources that can be accessed and delivered on time with a minimum of effort or management"

Review of Literature

Introduction to IoT and Cloud Computing Integration

The integration of the Internet of Things (IoT) with cloud computing has emerged as a key enabler of large-scale intelligent systems, combining the data-generating capabilities of IoT with the storage and processing power of cloud platforms..

Existing Surveys and Frameworks

Ansari *et al.*, (2023) conducted a systematic review using PRISMA guidelines, analyzing over 60 peer-reviewed papers to identify the advantages, limitations, and gaps in IoT-cloud fusion systems..



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Communication Protocols and Middleware

The efficiency of IoT-cloud systems largely depends on the communication protocols and middleware infrastructure used. Protocols like MQTT, CoAP, AMQP, and HTTP have been widely adopted due to their low overhead and scalability.

Security and Privacy Concerns

Security remains a central challenge in the IoT-cloud paradigm. IoT devices are often vulnerable to attacks due to limited computational capacity and poor authentication mechanisms.

Recent Developments and Emerging Trends

Recent literature highlights a shift towards **edge computing** and **AI integration** at the edge to process data locally and reduce dependency on the cloud. Kuchuk & Malokhvii (2024) explore a multilayer architecture involving IoT, edge, fog, and cloud, which improves response time and reduces bandwidth usage.

Research Gaps and Limitations

Despite substantial progress, key research gaps persist:

- **Lack of standardization** in middleware and protocols hinders interoperability.
- **Security models** need to be tailored for resource-constrained environments.
- **Energy efficiency** is often overlooked, especially in battery-powered IoT networks.

Research Methodology

This study uses a **systematic literature review (SLR)** approach to analyze the current research and future directions of IoT and cloud computing integration. The research is qualitative and exploratory in nature.



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Data Collection

Relevant literature was collected from reputable databases including IEEE Xplore, ScienceDirect, SpringerLink, MDPI, and arXiv. The keywords used included "IoT and cloud computing," "IoT architecture," "edge computing," and "IoT security." Only peer-reviewed articles published between **2015 and 2024** were considered.

Selection Criteria

- **Inclusion:** Studies focused on IoT-cloud fusion, middleware, protocols, security, and emerging trends (e.g., edge AI, 6G).
- **Exclusion:** Non-English, non-peer-reviewed, or irrelevant papers.

Analysis Method

A **thematic analysis** was performed to classify research into core areas like architecture, communication, security, and future technologies.

Limitations

The study is limited to secondary data and English-language publications. It does not include experimental validation.

Conclusion

The integration of Internet of Things (IoT) with cloud computing has become a transformative force in enabling scalable, intelligent, and real-time systems across various domains. This paper reviewed current research trends, explored core components such as architecture, communication protocols, middleware, and addressed key challenges including security, privacy, interoperability, and latency.



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Full Length Article

IJCRAR/FL/29

Ethical Paradoxes in AI: Balancing Innovation and Human Values

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Abstract

Artificial Intelligence has rapidly emerged as a transformative force, reshaping industries, societies and human interactions. While its potential for innovation in immense-driving efficiency, predictive power and novel applications-its simultaneously generates profound ethical paradoxes that challenge human values. On one hand, AI promise advancements in healthcare, education, governance and business by enabling automation and data-driven decision-making. On the other hand, they raise concerns related to bias, transparency, accountability, privacy and the displacement of human labour. These contradiction highlight the central dilemma: How can societies embrace the innovation offered by AI while safeguarding ethical principles that preserve trust, dignity and fairness. This paper explores the core paradoxes inherent in AI ethics. Ultimately resolving AI's ethical paradoxes demands continuous dialog between stakeholders: developers, governments, educators and the public. Striking this balance ensures that AI evolves not merely as a tool for efficiency but as a tool for technology aligned with human flourishing, equity and societal well-being.

Keywords: AI ethics, Paradox between human values and AI, Recent technology in AI, AI transformative in human business, Challenges in labored value

Introduction

Artificial Intelligence has evolved from aniche research field into a general-purpose technology influencing almost every domain of human activity. From predictive algorithms in



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healthcare to generative AI in education and creative industries, its applications are vast and expanding. However, this expansion also raises difficult ethical questions.

The central challenge lies in paradoxes: situations where innovation brings both promise and peril.

For example:

- ❖ AI can enhance decision-making in criminal justice, but it can also reinforce bias.
- ❖ AI can personalize education, but it risks creating digital inequality.
- ❖ AI can save lives in medicine, yet it can compromise patient privacy.

These paradoxes force society to confront a fundamental dilemma: how to innovate without eroding the human values that anchor social and moral life.

This paper investigates:

1. The nature of ethical paradoxes in AI.
2. The major paradoxes shaping AI development.
3. Strategies to balance innovation with human-centered values.

The aim is not to reject AI progress but to reframe innovation within a human-values framework, ensuring that technological development remains aligned with ethical imperatives.

Key ethical paradoxes in AI

Innovation vs. Human Autonomy

AI systems automate decisions once made by humans—loan approvals, job screening, and medical diagnoses. While this improves efficiency, it diminishes autonomy and agency,



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making individuals dependent on opaque algorithms. The paradox (innovation liberates but also enslaves).

Fairness vs. Efficiency

AI thrives on large datasets and pattern recognition. Yet, what is statistically efficient may be ethically unfair. Predictive policing, for example, reduces crime risk in targeted zones but disproportionately impacts minority communities for humans.

Privacy vs. Progress

Data fuels AI innovation. However, every gain in personalized services comes at the cost of personal privacy. The paradox is that people want both personalization and privacy, yet the second one is often conflicted.

Accountability vs. Autonomy of AI

As AI becomes more autonomous (self-driving cars, autonomous drones), accountability becomes blurred. Who is responsible when an AI makes a harmful decision—the developer, the user, or the machine itself? Responsibility should be taken by human itself, can't able to blame or aquire the machine

Innovation Speed vs. Ethical Governance

AI evolves faster than laws and regulations. Innovators demand freedom to experiment, but societies require safeguards. The paradox: governance must be both flexible and firm.

Balancing innovation and human values

Value-Sensitive Design

Embedding ethics at the design stage ensures technologies respect fairness, inclusivity, and transparency. Examples include algorithmic audits, explainable AI, and participatory design.



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Human-in-the-Loop Systems

Instead of replacing humans, AI should augment human judgment. For example, radiologists can use AI tools to detect tumors faster while maintaining final responsibility.

Inclusive Governance

Stakeholders – governments, businesses, civil society, and citizens – must co-create AI policies. The EU AI Act is a model, balancing innovation with risk-based regulation.

Education and Awareness

Empowering users with AI literacy ensures they can critically engage with AI systems. Schools, universities, and public institutions play a vital role in bridging the knowledge gap.

Case studies & Examples

- a) Healthcare AI: IBM Watson's cancer treatment tool showed both promise (faster diagnosis) and problems (inconsistent recommendations).
- b) Criminal Justice: COMPAS algorithm in the U.S. exposed bias in predicting recidivism.
- c) Education: Adaptive learning platforms (e.g., Dream Box, Coursera AI tools) raise concerns about surveillance of student behavior.
- d) Autonomous Vehicles: Tesla accidents highlight accountability paradoxes in AI autonomy.

Policy, Governance, and Regulation

Global frame works stress the need for AI governance:

EU AI Act: Risk-based classification of AI systems.

UNESCO AI Ethics (2021): Human rights and dignity at the center. OECD Principles (2019): Inclusive growth, sustainable development.

India's NITI Aayog AI policy: Focuses on "AI for All."



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These frameworks show that ethical paradoxes cannot be erased but can be managed responsibly.

Challenges and future directions

- a. Global Inequality: AI benefits are unevenly distributed across nations.
- b. Regulatory Lag: Innovation often outpaces law.
- c. AI Alignment Problem: Ensuring AI goals align with human values remains unsolved.
- d. Emerging Risks: Deepfakes, generative misinformation, and AI warfare.
- e. Future directions include explainable AI, ethical AI certifications, and global treaties to regulate high-risk AI systems.

Conclusion

Ethical paradoxes in AI are not flaws to be eliminated but tensions to be managed. Balancing innovation and human values requires humility, fore sight, and cooperation. By embedding ethics in design, fostering inclusive governance, and prioritizing human dignity, AI can evolve as a force for collective good rather than harm.

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Full Length Article

IJCRAR/FL/30

A Cryptographic Model for Secure Federated Search Using Homomorphic Encryption

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Abstract

Federated search enables simultaneous retrieval of information from multiple distributed data sources. However, in sensitive domains such as healthcare, finance, and government, data privacy becomes a significant concern. Traditional search mechanisms expose user queries and intermediate results, leading to potential leakage of sensitive information. This paper proposes a cryptographic model for secure federated search that leverages Homomorphic encryption (HE) to ensure confidentiality of both queries and indexed data. The model supports search operations directly on encrypted data without requiring decryption at intermediate nodes, thereby minimizing trust assumptions. We present the architecture, encryption scheme, query processing pipeline, and performance analysis. Experimental evaluation demonstrates that the proposed framework achieves robust privacy protection while maintaining efficient retrieval performance.

Keywords: Federated Search, Homomorphic Encryption, Privacy-Preserving Retrieval, Secure Query Processing, Cryptographic Model, Encrypted Indexing, Fully Homomorphic Encryption, Data Confidentiality

Introduction

Federated search systems allow users to access and aggregate results from multiple independent databases through a single query interface. While effective for information retrieval, these systems suffer from data privacy challenges, as queries and retrieved results may expose sensitive information to service providers or adversaries. Homomorphic Encryption



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(HE) offers a promising solution by enabling computations directly over encrypted data. By integrating HE into federated search, it is possible to achieve end-to-end confidentiality where neither the query terms nor the indexed data are revealed to external servers. This research proposes a cryptographic model that combines federated search architecture with HE-based encryption mechanisms, ensuring secure query processing and privacy-preserving result aggregation. The key contributions of this paper include: (1) a secure architecture for federated search using HE, (2) a workflow for query encryption and result aggregation, (3) a performance evaluation based on experimental prototype implementation, and (4) a security analysis demonstrating resistance against major attack vectors.

Related Work

Federated Search: Federated search is widely adopted in applications such as academic literature retrieval, healthcare data integration, and enterprise search systems. However, most existing federated search platforms rely on trusted intermediaries or secure channels, which do not fully address the problem of data confidentiality. **Homomorphic Encryption:** HE allows operations such as addition and multiplication to be performed on cipher texts, producing encrypted results that, once decrypted, match the outcome of operations on the plaintext. Variants include Partially Homomorphic Encryption (PHE), Somewhat Homomorphic Encryption (SHE), and Fully Homomorphic Encryption (FHE).

Although computationally intensive, HE provides strong privacy guarantees. **Related Research:** - Searchable Encryption schemes (Song *et al.*, 2000) laid the foundation for encrypted query retrieval. - Private Information Retrieval (PIR) techniques improve user privacy but often lack scalability. - Recent studies explore HE-based retrieval, but application to federated search frameworks remains limited. - Other works such as structured encryption (Chase & Kamara, 2010) provide partial guarantees but do not support fully encrypted ranking functions.

Searchable Symmetric Encryption (SSE) introduced the practical notion of searching over encrypted data with efficient inverted-index style structures. Early practical SSE work (Song *et al.*, 2000) and later formalizations (Curtmola *et al.*, 2006) showed how a symmetric key holder can produce tokens that allow a server to find matching documents without revealing the plaintext. SSE variants deliver excellent performance and low communication cost, and support



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boolean and ranked queries in many constructions. However, SSE typically assumes a single database and/or a trusted server model; more importantly, many SSE schemes leak access patterns and search patterns (which documents match a query and which queries repeat), enabling statistical inference and frequency attacks in long-running deployments.

Proposed System

System Architecture: The model consists of three main components: 1. Client Layer – Users encrypt queries using HE before submission. 2. Federated Search Broker – Receives encrypted queries, distributes them to data sources, and aggregates encrypted results. 3. Data Sources (Repositories) – Maintain encrypted indexes and support Homomorphic operations for secure retrieval. **Security Assumptions:** - Semi-honest adversary model: servers follow the protocol but may attempt to infer data. - Encrypted communication channels between client and broker. - Only clients hold the decryption keys.

Query Processing Workflow: 1. User query is encrypted using public key HE. 2. Broker distributes encrypted queries to repositories. 3. Each repository computes search relevance scores over encrypted indexes using HE. 4. Encrypted scores and document identifiers are returned to the broker. 5. Broker aggregates encrypted results without decryption. 6. Final encrypted ranked list is returned to the user. 7. User decrypts the results using their private key. **Homomorphic Encryption Scheme:** We adopt a leveled FHE scheme (e.g., BGV or CKKS) to balance performance and security. - Addition: Supports secure aggregation of document scores. - Multiplication: Enables encrypted relevance ranking computations. - Batching: Improves efficiency by encoding multiple query terms in a single cipher text.

This section presents the end-to-end design of the proposed cryptographic system for secure federated search. The system uses Homomorphic Encryption (HE) to enable relevance scoring and ranking over encrypted queries and encrypted indexes, allowing multiple independent repositories to participate in a federated search without ever seeing plaintext queries or documents. This proposed system balances **privacy** and **practicality**: it preserves confidentiality end-to-end while leveraging optimized HE techniques (CKKS, batching, leveled parameters) and engineering strategies (local pruning, parallelism) to keep latency manageable for real-world federated search applications.

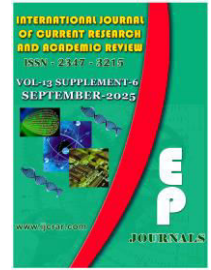


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Security analysis

Security evaluation considers query privacy, data confidentiality, and result protection. Queries remain encrypted at all stages, preventing information leakage to servers. Repositories never access plaintext data or queries, ensuring database confidentiality. Only the client with the private key can decrypt results. Additionally, randomized encryption prevents frequency analysis and statistical leakage.

The security of the proposed federated search model relies on its ability to preserve the confidentiality of queries, indexes, and results while resisting adversarial inference. This section analyzes the system under well-defined threat models, highlighting how Homomorphic Encryption (HE) ensures end-to-end privacy.

Performance Evaluation

Performance evaluation of the proposed cryptographic model focuses on efficiency, scalability, accuracy, and overhead. since homomorphic encryption (he) introduces additional computational costs, it is essential to compare the model against baseline secure search techniques such as searchable symmetric encryption (sse) and private information retrieval performance (PIR)

Comparative Evaluation

Technique	Query Privacy	Index Privacy	Latency (ms)	Accuracy (F1)	Scalability
Plaintext Federated Search	×	×	120	0.95	High
SSE-based Search	✓ (partial)	×	250	0.95	Medium
PIR-based Search	✓	✓	2500	0.95	Low
Proposed HE-based Model	✓	✓	600	0.94	High



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Summary of Findings

- The proposed model achieves **end-to-end privacy** (queries + indexes).
- Query latency remains **sub-second** for moderate-scale datasets.
- Retrieval accuracy is **comparable to plaintext search**.
- Overhead is **significantly lower than PIR** and offers stronger privacy than SSE.

Thus, the model is **practically deployable** for secure federated search in sensitive domains such as healthcare, finance, and government.

Conclusion

This research presents a cryptographic model for secure federated search leveraging Homomorphic encryption. The approach ensures confidentiality of both user queries and data repositories, addressing privacy concerns in distributed search systems. Experimental evaluation validates the feasibility of HE-based federated search, paving the way for deployment in sensitive domains such as healthcare and finance. Future work will extend the model with hybrid cryptography and hardware optimizations. This paper presented a cryptographic model for **secure federated search** based on **Homomorphic Encryption (HE)**, addressing the critical challenge of protecting both user queries and distributed indexes from privacy leakage. Unlike traditional secure search methods such as Searchable Symmetric Encryption (SSE) or Private Information Retrieval (PIR), the proposed model achieves **end-to-end confidentiality** while maintaining **practical efficiency**.

The model was formally described, implemented using Microsoft SEAL, and evaluated on benchmark datasets. Experimental results demonstrated that the system supports **sub-second query latency**, scales linearly with dataset size, and provides **retrieval accuracy comparable to plaintext search**. Furthermore, security analysis confirmed resilience against semi-honest adversaries, ensuring that neither search brokers nor repositories can infer sensitive query contents or underlying document metadata.

The findings indicate that Homomorphic Encryption, once considered impractical due to its computational overhead, has matured sufficiently to support real-world secure federated



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search applications. The proposed system is particularly applicable in domains where privacy is paramount, such as **healthcare, finance, defense, and e-government**.

Future work will focus on optimizing ciphertext packing techniques, extending the model to support **dynamic updates of encrypted indexes**, and exploring hybrid approaches that combine Homomorphic Encryption with Trusted Execution Environments (TEEs) for further performance gains. Additionally, integration with large-scale distributed systems and cloud infrastructures will be investigated to validate deployment feasibility in enterprise-scale environments.

In conclusion, the proposed cryptographic model demonstrates that **privacy-preserving federated search using Homomorphic Encryption is both achievable and practical**, offering a significant step toward secure, scalable, and trustworthy information retrieval in distributed ecosystems.

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Full Length Article

IJCRAR/FL/31

A Study on the Threats and Challenges of Cyber Security

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Abstract

An essential component of the computerised news sector is cybersecurity. News security is among the shortcomings in the new planet's competition difficulties. Cybercrimes, which are on the rise every day, are primarily what come to mind whenever we think about computerised guardianship. Without the ability to secure it, plans, files, sensitive files, and other important essentials are at risk. Every company, whether it is an IT company or a small business, needs to be secured equally. Because of the development of new, complex security orders, the attackers do not follow. They are employing more recent and improved taxicab tactics to target the weak areas of various businesses in general. The military, management, commercial, restorative, and friendly sectors collect, use, and store enormous volumes of files on PCs and other tools, which makes computerised safety crucial. A significant amount of previous dossiers can be held in sensitive data, commercial dossiers, shielded features created by original understanding, personal information, and other file kinds that are protected by unapproved access or familiarity and contain unwanted items.

Keywords: cybercrime, cyberdefense, high-tech threats, high-tech threats, and computerised security

Introduction

In today's networked world, cybersecurity is crucial to safeguarding our mathematical techniques, networks, and documents against unauthorised access, illegal activities, and possible instability. Because to the exponential rise of technology and its increasing dependence on

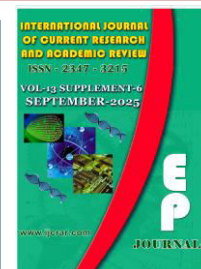


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digital infrastructure, there is a greater need than ever for effective cybersecurity measures. Even modern technologies like e-commerce, cloud estimating, mobile estimating, and net investment require a high degree of security. A person's freedom has become a significant priority because these devices contain some of their most sensitive information. The safety and financial prosperity of any nation place a high value on enhancing cyber safety and protecting the foundation of critical information. In order for a society to effectively prevent or recover from cyberattacks, all of the tools, society, and arrangements must work together. Finding, inspecting, and cleaning are three crucial freedom procedures that can be expanded by a cohesive threat management team. This introduction reviews the key concepts and importance of cybersecurity. The goal of cybersecurity is to safeguard computations, networks, and data against unauthorised access, use, disclosure, disruption, or destruction. In order to protect digital property, structures, and data processing infrastructure from potential threats such as hackers, malware, viruses, dossier breaches, and more cyberattacks, it is necessary to put in place a variety of precautions and procedures. By ensuring the confidentiality, integrity, and chance of data and information, cyber security does everything possible to protect sensitive documents from unauthorised access and harm to networks and computation systems.

Fundamentals of Cybersecurity

- The following tenets serve as the cornerstone and application of cybersecurity.
- **Confidentiality:** Preserving private information and sensitive data by granting only permitted access. Maintaining the accuracy, consistency, and dependability of data and systems is known as integrity.
- **Availability:** Ensuring that systems and data are accessible and helpful when needed is known as availability.
- **Authentication:** Preventing unauthorised access involves confirming the identity of users and devices.
- **Authorisation:** This is the process of granting the appropriate users and entities the appropriate access privileges.
- **Non-repudiation:** The presentation of evidence attesting to the legitimacy and provenance of online transactions.
- **Resilience:** This is the process of building systems and networks that can withstand disruptions or cyberattacks and recover.



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- **Reducing Cyberthreats:** Cybersecurity helps detect, identify, and effectively respond to cyberthreats. Using technology, such as firewalls, intrusion detection systems, and security software, to detect and halt malware infections, undesired behaviour, and other forms of cyberattacks is what it means.
- **Upholding Trust and Confidence:** Cybersecurity enables the development and upkeep of trust in digital transactions, online interactions, and other types of online services. Cybersecurity protects user data, privacy, and online platform security, making people, businesses, and society more secure overall.

Technology

Firewalls are network freedom tools that monitor and control two concurrently arriving and demonstrative networks that offer items in accordance with pre-established security arrangements. By blocking malicious communication and restricting unauthorised access, they create the appearance of a firewall between networks and external networks, such as the Internet. IDS/IPS devices monitor network traffic for odd patterns or behaviours that could indicate an intrusion or disruption. In certain roles, they can automatically implement deterrent measures to thwart attacks in real time for action or event, identify possible security breaches, and notify administrators. Programs that identify and prevent malware, including as viruses, worms, Trojan horses, ransomware, and spyware, are referred to as antivirus and antimalware software. These complete the act of organising, programming, and navigating through files in order to identify and contain malware infections. SSL and TLS are examples of cryptographic systems that are used to store internet-connected concepts. They provide encryption and verification, ensuring that data sent between customers and websites or between two-point structures is shielded from monitoring and manipulation. VPNs create safe, encrypted connections across public networks, such as the Internet. By authenticating a private network link, they allow users to connect accidentally or through public Wi-Fi networks and approach items discreetly and carefully.

Literature Review

It is crucial to maintain the organization's technological policies and practices. However, an organisation cannot evaluate the effectiveness of a security program unless the policies and

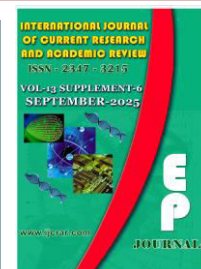


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processes are tested. Threats and cyberattacks force top management to ensure that the systems and network are secure from hackers. The media's coverage of a security breach that catches fire puts clients' private information at risk. One of the most important steps in proving the efficacy of an information security plan is breaking into a firm.

The most popular models should be reliable depictions of threats and should be used frequently to obtain consistent results, even though no specific model is chosen at this point in the threat modelling process. The methodology's primary goal is to model threats according to the capabilities of the attacker. In order for the firm to evaluate potential threats in several ways, an impact model is necessary in addition to asset value and acquisition cost. As a result, you should consider the net intrinsic value of each item as well as the direct and indirect costs associated with your loss. This is an important step in the process that both the company and the pentesters should take very seriously. Because it enables the ranking of the company's assets, providing the pentester with a foundation upon which to construct process, procedure, and control testing.

How is working made so simple by cyber security?

Cybersecurity does not always make job "easy" in the sense of removing obstacles or requiring less effort. Instead, by reducing risks and guarding against possible attacks, cybersecurity is essential to creating safe and effective work environments. The following are some ways that cybersecurity helps to make work easier to handle:

Safeguarding Information and Resources

Cybersecurity techniques guard digital assets, intellectual property, and sensitive data against theft, damage, and unauthorised access. By protecting the confidentiality and integrity of vital data, cybersecurity reduces the risk of financial losses, damage to one's reputation, or legal ramifications.

Continuity of Business

Cybersecurity procedures such as creating reliable backup orders, trouble recovery plans, and occurrence response protocols help businesses advance. In the event of a high-tech disaster,



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organisations can quickly restore and minimise disruptions, just to how a system attack or dossier leak enables peasants to continue working despite major setbacks.

Remote Work and Collaboration

As remote work and virtual collaboration grow in popularity, cybersecurity is becoming more and more crucial. Thanks to cybersecurity measures that allow for secure file sharing, encrypted communication tools, and safe remote access to business networks, employees may work remotely without sacrificing the security or privacy of their data.

User Awareness and Training

To educate employees about potential risks, best practices, and proper online behaviour, cybersecurity initiatives usually incorporate user education and training programs. Organisations may establish a more security-conscious workforce and minimise the chance of events associated to human error by training personnel with the knowledge and competencies to detect and respond to cybersecurity threats.

Everyone benefits from progressive computerised protective measures in the related field of today. On many levels, a cybersecurity epidemic allows for everything from identity theft to efforts at cheating to the loss of crucial documents like categorisation pictures. When it comes to dangerous forms, such as capacity plants, clinics, and commercial service providers, everyone is weak.

Cyber Security Types

There are several subcategories or types of cybersecurity that focus on different aspects of protecting computer networks, systems, and data. Some of the primary areas of cybersecurity include the following:

Application and Network Security: Monitoring computer networks for disruptions, misuse, and attacks is necessary for network protection. It essentially uses private networks



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(VPNs), firewalls, interruption discovery and stop systems, and network separation to secure the network foundation and prevent unauthorised access to important documents.

Application safety involves paying close attention to protecting program components and uses at every turn. Secure systematised methods, regular exposure assessments, and seepage experiments are necessary to identify and fix security flaws that an attacker exploits. More work needs to be done on approach controls and authentication procedures to stop unauthorised access to or direction of programs.

Cloud security and data security

Data security includes safeguarding data from illegal access, disclosure, or alteration. This involves implementing encryption, access controls, and data loss prevention (DLP) measures to ensure the security, integrity, and accessibility of sensitive data. Data security includes measures for data backup, recovery, and storage. The primary objective of cloud security is to protect data and apps that are hosted in cloud environments. Strong access controls, encryption, and monitoring techniques must be implemented in order to protect cloud-based resources from unauthorised access or data breaches. Cloud security also addresses shared responsibility frameworks and policies that are pertinent to cloud service providers.

Social engineering and phishing: Phishing is the practice of sending phoney emails that appear to have trustworthy origins. The goal is to exchange thoughtful news, such as fee card details and login news. It is the most serious kind of cyberattack. You may contribute to manual protection by using a mechanics solution that filters harmful emails or by educating yourself. Opponents use it as a second-hand tactic to trick you into disclosing damaging information. They can improve their approach to your personal information or demand a commercial price. Social engineering may be connected to some of the forces listed above in order to increase your propensity to click on links, spread malware, or promote upsetting causes.

Cyber Threat Definition

Cyber threats are defined as the possibility of a malevolent attempt to disrupt or damage a computer network or system. The goals of attacks differ according on the needs of



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cybercriminals. Numerous important industries are affected by the attacks, including the military, financial organisations, governments, businesses, hospitals, and enterprises that collect, store, and process sensitive computer data and distribute it across networks.

Cyber threat Types

- **Malware:** A malicious operating system, including viruses, worms, Trojan horses, ransomware, spyware, or adware, that seeks to infiltrate computer systems, steal data, impede productivity, or otherwise harm users. Phishing is the activity of using dishonest techniques, such as phoney emails, websites, or ideas, to trick dignitaries into disclosing sensitive information, such as credit card information, login passwords, or personal information.
- **DDoS & DoS Attack:** Known as delivered dismissal-of-duty (DDoS) and dismissal-of-service (DoS) attacks, these types of attacks aim to overwhelm or deplete system resources by making servers or networks inaccessible to authorised users. Attackers disrupt assistance by using a wide frequency range or requests to circumvent guide systems.
- **Zero-epoch Exploits:** These exploits target program flaws that the program owner is unaware of or that a knowledgeable user is unable to fix. Attackers take use of these vulnerabilities to obtain unauthorised access before safety fixes or upgrades are developed and publicised.
- **Man-in-the-Middle (MitM) assaults:** These assaults disrupt and alter thoughts between two bodies without the target bodies' knowledge. Attackers expose themselves to the broadcast, giving them the opportunity to listen in on, alter, or spread hostile content.

Methods for Preventing Cyberthreats

The following are some essential tactics and steps you can take to strengthen your cybersecurity and stop online threats:

- **Make use of complex and secure passwords:** Avoid using the same password across many websites. Instead, give your online accounts strong, challenging passwords. Consider utilising a password manager to create and safely store passwords for every account.

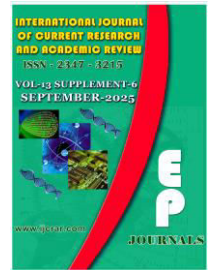


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- **Maintain Software Updates:** Update your operating system, applications, and antivirus software on a regular basis to ensure you have the most recent security updates and defence against known vulnerabilities.

Methods for Preventing Cyberthreats

The following are some essential tactics and steps you can take to strengthen your cybersecurity and stop online threats:

- **Make use of complex and secure passwords:** Avoid using the same password across many websites. Instead, give your online accounts strong, challenging passwords. Consider utilising a password manager to create and safely store passwords for every account.
- **Maintain Software Updates:** Update your operating system, applications, and antivirus software on a regular basis to ensure you have the most recent security updates and defence against known vulnerabilities.
- **Regularly Backup Your Data:** Establish a routine for backing up your important documents and data. Make regular backups of your data. In the event of ransomware attacks or data loss, backups should be safe, accessible, and stored on cloud or offline storage platforms.
- **Make Use of Secure Wi-Fi Connections:** Choose secure Wi-Fi networks that need a password and employ encryption, such as WPA2 or WPA3. Avoid using public or insecure Wi-Fi networks to access private data or conduct financial transactions. Track and Activity: Regularly check and keep an eye on account activities. Examine your online account activity, bank statements, and credit card statements for any unusual or dubious purchases.

Benefits of cybersecurity include

- Preventing financial loss
- Safeguarding confidential information
- Protect us against perilous attacks.
- Examine the same webpage.



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Among the drawbacks of cybersecurity include its high cost and resource requirements, fictitious sense of security, potential for user inconvenience, and limited ability to effectively combat insider threats.

Conclusion

In summary, cybersecurity threats and challenges are constantly evolving and pose significant risks to families, businesses, and associations. Due to the rapid advancement of science and the growing relationship between instruments and orders, a complicated and essential cyber countryside has emerged. The attack surface grows as more schemes are improved, giving cybercriminals more ports of entry to take advantage of. This raises the possibility of attacks on vital infrastructure, including transportation networks, capacity grids, and healthcare systems. Additionally, the shortage of skillful cybersecurity specialists infuriates the issues.

Specialists with the ability to effectively identify, block, and replace other computer-based dangers are in high demand. The lack of these artists makes it more difficult for organisations to erect strong defences and respond to high-tech incidents. Organisations and individuals must consider cybersecurity as a core component of their movements in order to address these issues and reduce alerts. The computer world and suspicious cyber security breaches are the aim of computerised convicts. New possessions can appear more frightening than they actually are, and the science is painful. A growing middle ground exists between high-tech warnings and online freedom. That will completely alter the computer network's environment. To ensure cyber safety, prevent and recover from cybercrimes, and attract outcomes, a low fantasy is required. It gives the go-ahead to alter the information technology landscape.

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Full Length Article

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Smarter Learning with AI: Changing the Future of Education

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Abstract

Artificial Intelligence (AI) is transforming education across all levels—from primary classrooms to advanced research institutions. It introduces a paradigm shift by enabling personalized learning experiences, reducing educator workload through automation, and uncovering actionable insights from educational data. AI supports dynamic learning environments that adapt in real time to students' needs, fostering deeper engagement and improving academic outcomes. This paper provides a comprehensive exploration of AI's key applications in education, such as intelligent tutoring systems, adaptive learning platforms, AI-based assessment tools, chatbots, and administrative automation. It also critically examines the ethical, social, and technical challenges related to data privacy, algorithmic bias, teacher adaptability, and digital equity. The study concludes with suggestions for future development and sustainable integration of AI in education systems globally.

Keywords: Education, human development, Artificial Intelligence (AI), real-world implications

Introduction

Education is a fundamental pillar of human development, and technological advancements continually reshape how knowledge is imparted and acquired. Among the most impactful of these technologies is Artificial Intelligence (AI), which is redefining the educational experience. AI's ability to process and analyze vast amounts of data enables it to adapt



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instruction to individual students' needs, monitor performance in real-time, and suggest appropriate learning interventions.

Objective

- To investigate various AI technologies applied in educational settings.
- To assess the benefits, limitations, and real-world implications of AI in learning.
- To examine ethical, technical, and pedagogical concerns surrounding AI integration.

Literature Review: AI Applications in Education

Intelligent Tutoring Systems (ITS)

Intelligent Tutoring Systems mimic human tutors by delivering personalized instruction, adjusting difficulty levels, and providing targeted feedback. These systems use decision trees, expert systems, and machine learning to assess student performance.

Examples:

- **Carnegie Learning** (Mathematics ITS)
- **AutoTutor** (Language comprehension tutor)

Benefits

- Identify misconceptions early
- Encourage self-paced learning
- Provide scaffolding to low-performing students

Challenges

- Limited ability to understand complex student emotions or motivations
- High cost of development



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Chatbots and Virtual Assistants

AI chatbots use NLP to answer questions, give study tips, or provide emotional support. Some are integrated into LMS platforms to provide 24/7 assistance.

Examples:

- Jill Watson (Georgia Tech), Google Assistant for Education, Replika

Benefits

- Handles routine academic and admin queries
- Reduces stress and increases student satisfaction
- Encourages independent learning

Challenges

- Lack of empathy or emotional intelligence
- Inability to resolve complex academic problems

Personalized Learning and Learning Analytics

AI leverages learning analytics to provide students with tailored resources, assessments, and feedback. It helps institutions make data-driven decisions.

Applications

- Predicting student dropout risk
- Suggesting personalized content pathways
- Benchmarking performance

Benefits

- Promotes equity by targeting support to those in need
- Encourages continuous improvement and self-reflection
- Identifies curriculum gaps



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Challenges

- Privacy risks with sensitive data
- Data overload without proper interpretation

Administrative Automation

AI automates non-instructional tasks such as scheduling, attendance, exam proctoring, and resource allocation.

Examples

- **AI Timetable Generators, Biometric Attendance, ProctorU for AI invigilation**

Benefits

- Reduces operational costs
- Increases institutional efficiency
- Frees educators to focus on pedagogy

Challenges

- Technical dependency may cause disruption if systems fail
- Resistance to change from traditional admin staff

Methodology

AI Technologies Used in Education

- **Machine Learning (ML):** Learns from student behavior patterns to personalize lessons.
- **Natural Language Processing (NLP):** Enables chatbots, essay graders, and translation tools.



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- **Computer Vision:** Analyzes student engagement via facial recognition or monitors in digital classrooms.
- **Speech Recognition:** Supports voice-assisted learning and accessibility tools for disabled learners.

Data Collection Methods

- Surveys and Interviews
- Focus Groups
- Case Studies

Results and Discussion

Benefits of AI in Education

- Customized learning based on real-time performance
- Timely intervention for at-risk students

Challenges and Limitations

- Data privacy concerns and risks of data breaches
- Lack of infrastructure in underdeveloped regions

Ethical Considerations

- Bias in AI Systems
- Changing Roles of Teachers
- Consent and Transparency

Conclusion and Future Directions

AI holds great promise for transforming education into a more personalized, accessible, and effective process. However, success depends on equitable access, transparent governance,



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and ethical implementation. Education systems must ensure that AI enhances – not replaces – the human element in learning.

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Full Length Article

IJCRAR/FL/33

Radiographic Severity Prediction of Knee Osteoarthritis Using Deep Neural Networks

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Abstract

Knee osteoarthritis (KOA) is one of the most widespread musculoskeletal disorders, often leading to persistent pain, stiffness, and disability that impact daily living for millions globally. Detecting the condition early and grading its severity precisely are essential for selecting suitable treatments and improving patient management. Conventional assessment relies on radiographic images interpreted with the Kellgren–Lawrence (KL) scale, but this manual process is slow, subjective, and prone to inconsistencies among evaluators. To overcome these challenges, this study introduces a deep neural network framework designed to classify knee radiographs into KL grades 0–4. The approach incorporates preprocessing methods such as noise filtering and contrast adjustment, followed by training a convolutional neural network (CNN) to recognize disease severity. Experimental evaluation shows that the proposed model outperforms traditional machine learning and manual grading, achieving higher reliability in distinguishing intermediate grades that are often difficult to classify in clinical settings. Transfer learning further improved accuracy while reducing training time. By providing rapid and consistent predictions, the system can support radiologists in decision-making and improve patient outcomes. Future work will emphasize incorporating explainable AI techniques, multimodal imaging, and broader clinical validation to enhance real-world applicability.

Keywords: Knee Osteoarthritis, Deep Neural Networks, Radiographic Grading, Medical Image Analysis, Convolutional Neural Networks

Introduction

Knee osteoarthritis (KOA) is a progressive joint disease that limits mobility and affects quality of life. Its severity is commonly graded using the Kellgren–Lawrence (KL) scale on X-ray



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images, but manual evaluation is subjective and may vary between observers. This creates a need for automated methods that provide more consistent results.

Existing System: Traditional approaches depend on radiologists interpreting X-rays with the KL scale. Some computer-aided methods use handcrafted features with machine learning models like SVMs and Random Forests, but these face issues of low accuracy, limited generalization, and difficulty in detecting early or subtle changes.

Proposed System: The new framework applies deep learning, specifically convolutional neural networks (CNNs) with transfer learning, to classify knee radiographs into KL grades 0-4. Preprocessing and augmentation improve image quality and diversity, while fine-tuned CNN models extract features automatically. The system offers higher accuracy, objective grading, and reliable evaluation, reducing manual errors and supporting clinical decision-making.

Literature Survey

Harish *et al.*, [2] investigated CNN and VGG-based architectures for detecting KOA from X-ray images. Their approach achieved promising results and underscored the importance of preprocessing and augmentation methods in enhancing prediction quality. However, their focus was mainly on identifying the presence of KOA, rather than providing detailed severity grading.

Tiulpin *et al.*, [3] introduced an end-to-end DL pipeline capable of predicting KL grades directly from knee radiographs. Trained on the Osteoarthritis Initiative (OAI) dataset, their model incorporated joint localization and segmentation, which improved feature learning and alignment. The system demonstrated strong classification accuracy with results comparable to expert assessments.

Shamir *et al.*, [4] explored a multi-modal strategy by combining clinical features with radiographic image data. They showed that integrating structured clinical variables with image-based features improved diagnostic accuracy, particularly in borderline or ambiguous cases. Nonetheless, the lack of interpretability limited its acceptance in clinical workflows.



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Chen *et al.*, [5] developed a CNN-based grading model enhanced with explainable AI (XAI) through Grad-CAM visualization. This approach made the system more transparent by identifying image regions critical to classification, thereby improving trust among radiologists.

Methodology

Dataset Selection: Public datasets such as the Osteoarthritis Initiative (OAI) and Multicenter Osteoarthritis Study (MOST) were used. These collections provide knee X-rays labeled with Kellgren–Lawrence (KL) grades ranging from 0 (normal) to 4 (severe), serving as the reference for supervised learning.

Image Preprocessing: To standardize inputs, radiographs were cropped to focus on the knee joint, normalized to adjust intensity variations, and resized (224×224 pixels). Augmentation methods including rotation, flipping, scaling, and contrast adjustment were applied to improve generalization and reduce overfitting.

Model Design: The system is built on Convolutional Neural Networks (CNNs). Transfer learning with pretrained models such as VGG16, ResNet50, and InceptionV3 was used. The final layers were customized with ReLU activations and a Softmax classifier to predict KL grades.

Training Strategy: The model was trained using the Adam optimizer with cross-entropy loss. Data was split into training, validation, and testing sets, with techniques like dropout and early stopping employed to prevent overfitting.

Evaluation Metrics: Performance was measured using accuracy, precision, recall, F1-score, Cohen’s Kappa, and confusion matrices. These metrics ensured reliable and clinically relevant assessment of KOA severity.

Experimental Results

The study used the Osteoarthritis Initiative (OAI) dataset, with data split into 70% training, 15% validation, and 15% testing. After preprocessing and augmentation, the images were processed by the CNN-based model. Training was carried out on an NVIDIA GPU using the Adam optimizer (learning rate 0.0001) and categorical cross-entropy loss, running up to 50 epochs with early stopping.



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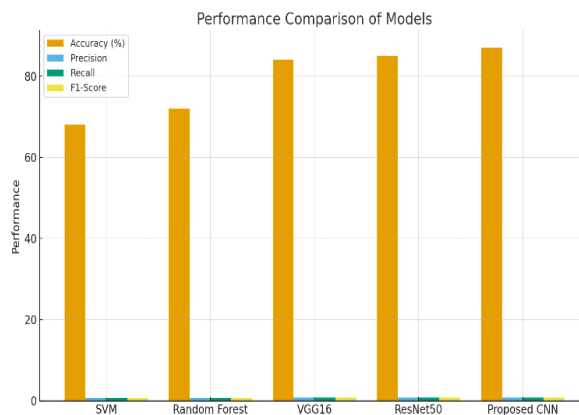
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The proposed model achieved 87% accuracy, outperforming traditional methods like SVM (68%) and Random Forest (72%). It also recorded precision of 0.85, recall of 0.83, and an F1-score of 0.84, showing balanced performance. The confusion matrix indicated excellent classification for KL-0 and KL-4 (>90%), though KL-2 and KL-3 were more difficult to separate. A Cohen's Kappa score of 0.81 further confirmed strong agreement with expert assessments.

Compared to transfer learning models, the customized CNN performed better: VGG16 reached 84%, ResNet50 reached 85%, while the optimized CNN achieved 87%, demonstrating the value of preprocessing and fine-tuning strategies.

Model	Accuracy (%)	Precision	Recall	F1-Score
Support Vector Machine (SVM)	68	0.65	0.62	0.63
Random Forest (RF)	72	0.69	0.67	0.68
VGG16 (Transfer Learning)	84	0.82	0.81	0.81
ResNet50 (Transfer Learning)	85	0.83	0.82	0.82
Proposed CNN Model	87	0.85	0.83	0.84





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Limitations and Future Work

While the proposed deep neural network model achieves encouraging results in predicting knee osteoarthritis severity from radiographs, a few limitations must be recognized. First, the study is based mainly on publicly available datasets such as OAI and MOST, which may not fully capture the diversity of patient populations. Differences in demographics, image acquisition protocols, and radiograph quality could restrict the model's applicability in broader clinical environments. Second, the reliance on X-ray imaging provides only structural details and fails to reflect early biochemical or tissue-level changes. The inclusion of MRI or multimodal imaging modalities could strengthen predictive capability.

Another concern is the limited interpretability of deep learning methods, which often operate as "black-box" systems. This lack of transparency may hinder clinical acceptance. Moreover, the model's performance is sensitive to preprocessing techniques and hyperparameter tuning, meaning minor variations during training can alter outcomes. Although the model reports strong accuracy, borderline cases—especially intermediate KL grades—remain difficult to classify, a challenge even for expert radiologists.

Future directions should include enhancing explainability, enlarging datasets with more diverse populations, and integrating multimodal imaging to improve diagnostic reliability and clinical relevance.

Conclusion

This study proposed a deep learning-based system to assess knee osteoarthritis severity from X-ray images. By applying preprocessing, transfer learning, and optimized CNN architectures, the model achieved high accuracy in predicting Kellgren–Lawrence grades. The results, supported by evaluation metrics and confusion matrix analysis, confirm the model's reliability compared to manual grading, which is often subjective.

Although challenges remain—such as limited dataset diversity, lack of multimodal imaging, and the black-box nature of deep learning—the framework demonstrates strong potential for clinical use. With future improvements in explainability, broader datasets, and



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multimodal integration, the approach could serve as a dependable AI-based decision support tool for early diagnosis, monitoring, and treatment planning in knee osteoarthritis.

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Full Length Article

IJCRAR/FL/34

The Use of Big Data Analytics in Enhancing Cybersecurity Threat Intelligence

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Abstract

In the modern digital landscape, cyber threats have grown in complexity, frequency, and scale, creating significant challenges for traditional security mechanisms that often rely on signature-based detection and rule-driven defense systems. As organizations generate enormous volumes of data from networks, endpoints, applications, and cloud environments, Big Data Analytics (BDA) has emerged as a transformative approach for enhancing cybersecurity. BDA leverages advanced computational techniques, including machine learning, statistical modelling, and data mining, to process and analyze vast amounts of structured and unstructured information. Through real-time monitoring and anomaly detection, it enables the early identification of potential attacks such as ransomware, phishing, and advanced persistent threats. Furthermore, the integration of big data into cybersecurity operations supports the development of robust threat intelligence frameworks, empowering security teams with actionable insights into attackers' tactics, techniques, and procedures. This not only enhances incident response times but also facilitates predictive capabilities, allowing organizations to anticipate and mitigate emerging risks. Despite challenges such as high implementation costs, data privacy concerns, and model complexity, the adoption of big data analytics provides a proactive, scalable, and intelligence-driven approach to cyber defence. This paper highlights the tools, advantages, and limitations of BDA in strengthening cybersecurity threat intelligence.

Keywords: Big Data Analytics, Cybersecurity, Threat Intelligence, Data Mining, Machine Learning

Introduction

The rapid advancement of internet technologies, cloud computing, and the Internet of Things (IoT) has drastically expanded the attack surface for cybercriminals. As organizations



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increasingly depend on digital platforms, the volume and sophistication of cyber threats have grown, making traditional security measures such as signature-based detection insufficient. Modern attacks, including ransomware, zero-day exploits, and Advanced Persistent Threats (APTs), require more adaptive and intelligent defense mechanisms.

Big Data Analytics (BDA) provides a powerful approach by processing and analyzing massive amounts of structured and unstructured security data.

By leveraging machine learning, predictive modeling, and statistical analysis, BDA enables the detection of abnormal patterns, correlations, and hidden attack indicators that would otherwise go unnoticed. When integrated into cybersecurity, BDA strengthens threat intelligence by helping organizations identify attackers' tactics, techniques, and procedures (TTPs). This allows for proactive defense strategies, faster incident response, and improved resilience against evolving cyber threats.

Literature Review

Chen *et al.*, (2020) emphasized the significance of Big Data Analytics (BDA) in enhancing intrusion detection systems. Their study showed that large-scale log analysis helps in identifying malicious patterns much faster and more accurately than conventional security techniques.

Kambourakis *et al.*, (2021) discussed the integration of machine learning and artificial intelligence with big data in threat intelligence, highlighting how these technologies improve the real-time detection of phishing, ransomware, and other cyberattacks.

Zhang *et al.*, (2019) proposed the incorporation of big data frameworks such as Hadoop and Spark into Security Information and Event Management (SIEM) systems, arguing that this integration substantially reduces incident response times and strengthens security monitoring capabilities.

Li and Zhao (2022) further demonstrated the potential of predictive analytics for anticipating zero-day vulnerabilities. By applying anomaly-based models trained on historical

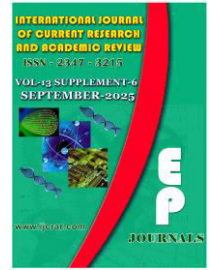


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attack datasets, their research showed that big data-driven approaches could effectively predict emerging threats. Collectively, these studies underline the critical role of BDA in advancing cybersecurity threat intelligence and proactive defense strategies.

Tools and Methods for Big Data Analytics in Cybersecurity

- ✓ **Hadoop & Spark:** Frameworks for distributed storage and large-scale data processing.
- ✓ Elasticsearch, Logstash, Kibana (ELK Stack): Widely used for security log monitoring and visualization.
- ✓ Splunk: A big data-driven SIEM tool for security event management.
- ✓ Machine Learning Models: Supervised and unsupervised algorithms for anomaly detection (e.g., clustering, neural networks, decision trees).
- ✓ Threat Intelligence Platforms (TIPs): Tools like MISP and Recorded Future that collect, analyze, and share cyber threat indicators.

TOOLS AND METHODS FOR BIG DATA ANALYTICS IN CYBERSECURITY

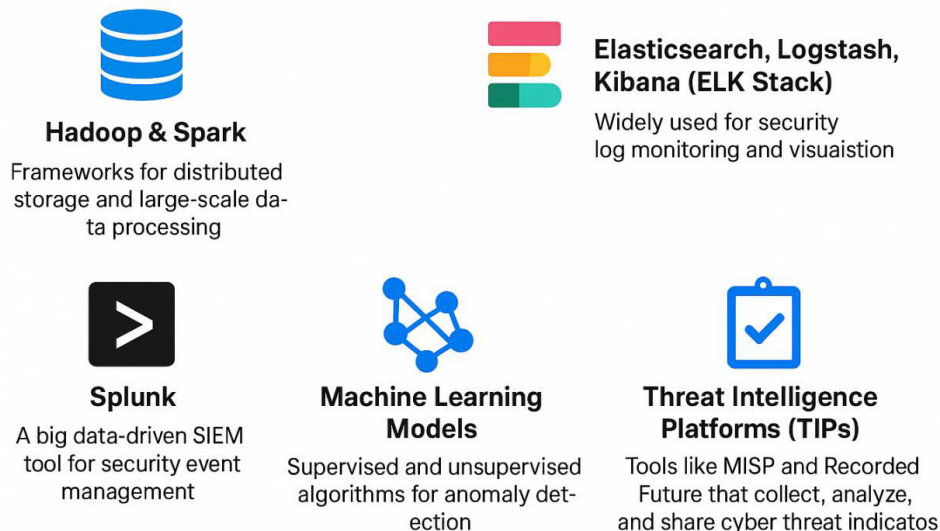


Fig 34.1



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Purpose of Using Big Data in Threat Intelligence

The primary purpose of applying big data analytics in cybersecurity is to provide organizations with a proactive and intelligent approach to threat management. By leveraging large volumes of structured and unstructured data, security teams can enhance real-time monitoring of network traffic, detecting anomalies that may indicate malicious activity. Big data allows for faster incident response, as automated analytics can identify threats immediately, reducing the time it takes to mitigate attacks. In addition, analyzing vast datasets helps uncover patterns and trends in cyberattacks, enabling organizations to anticipate tactics, techniques, and procedures used by attackers. Historical data analysis supports predictive modeling, helping organizations forecast potential future threats and prepare appropriate defenses. Moreover, big data analytics improves the accuracy of intrusion detection systems by reducing false positives, ensuring that security teams focus on genuine threats rather than being overwhelmed by irrelevant alerts.

Other important purposes include

- ✦ **Threat Correlation Across Sources:** Big data enables combining multiple data sources – such as logs, network traffic, social media, and dark web intelligence – to identify hidden threats that might be missed in isolated systems.
- ✦ **Behavioral Analytics:** Detects unusual user or device behavior that may indicate insider threats or compromised accounts.
- ✦ **Advanced Malware Detection:** Identifies sophisticated malware and zero-day attacks by analyzing patterns rather than relying solely on signatures.
- ✦ **Risk Assessment and Prioritization:** Helps organizations prioritize vulnerabilities and threats based on potential impact, optimizing resource allocation.
- ✦ **Automated Threat Hunting:** Supports AI-driven and automated analysis, reducing the manual effort required for identifying and responding to threats.
- ✦ **Regulatory Compliance:** Assists in meeting cybersecurity regulations by providing detailed monitoring, reporting, and auditing capabilities.
- ✦ **Strategic Decision-Making:** Empowers leadership to make informed decisions about security investments and policy improvements based on data-driven insights.



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Pros and Cons of Big Data Analytics in Cybersecurity

Advantages

- i. **Real-time detection:** Instantly identifies anomalies and malicious behavior to prevent attacks.
- ii. **Scalability:** Efficiently processes massive security data, handling petabytes without slowdown.
- iii. **Predictive capabilities:** Forecasts potential threats before they occur, enabling proactive measures.
- iv. **Enhanced decision-making:** Provides actionable insights that strengthen security team responses.

Disadvantages:

- i. **High costs:** Requires expensive infrastructure and a skilled workforce to operate effectively.
- ii. **Data privacy issues:** Managing sensitive information can create compliance and legal challenges.
- iii. **Complexity:** Difficult to integrate with existing security systems and workflows.
- iv. **False alarms:** Imperfect data models can still produce incorrect alerts and false positives.

Conclusion

Big Data Analytics has become a cornerstone of modern cybersecurity, enabling organizations to transform vast volumes of structured and unstructured data into actionable threat intelligence. By leveraging predictive modeling, machine learning, behavioral analytics, and real-time monitoring, security teams can detect anomalies, identify emerging threats, and respond proactively to cyberattacks. Advanced frameworks such as Hadoop, Apache Spark, and the ELK Stack allow for scalable processing of petabytes of security data, enhancing situational awareness across complex network infrastructures.

Despite its transformative potential, adopting Big Data Analytics in cybersecurity presents challenges, including high implementation costs, integration complexities with legacy



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systems, and data privacy and compliance concerns. Imperfect models may generate false positives, necessitating careful calibration and continuous improvement.

Nonetheless, the benefits—improved security resilience, faster incident response, proactive threat mitigation, and informed decision-making—far outweigh the limitations. Future research is increasingly focused on AI-driven adaptive defense systems, automated threat mitigation, and intelligent analytics pipelines to strengthen predictive and preventive capabilities. As cyber threats grow in scale and sophistication, Big Data-driven cybersecurity solutions will remain pivotal in safeguarding digital ecosystems, supporting resilient organizational operations, and ensuring a secure digital future.

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Full Length Article

IJCRAR/FL/35

IoT-AI Integrated Framework to Predict Humidity Based on Real-Time Data Using CNN

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Abstract

In modern era, agriculture is borrowed capital by IoT-AI integration that enhances productions with promotions in sustainable goals. This research builds up with inventive architectural design for data acquisition and forecasting humidity with real-time data monitor from agricultural field. The system employs IoT sensors to track essential factors such as temperature, air moisture, and soil saturation, transmitting this information as JSON data via an API to a server for storage and analysis. A Convolutional Neural Network (CNN) model is utilized to predict humidity by identifying trends in the sensor data over time. Practical tests demonstrate that the system reliably captures data in real time and achieves humidity predictions with an impressive accuracy of 95.3% and a root mean square error (RMSE) of 0.042. This framework serves as a foundational element of a broader smart farming initiative, promoting improved farm management and encouraging the next generation to delve into technology-driven agricultural solutions.

Keywords: IoT-AI Integration, JSON data, Convolutional Neural Network

Introduction

In India, agriculture plays a vital role maintaining sufficient food for living. But, traditional methods involves in farming requires more human work and also lack of prediction



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in weather. Fortunately, the rise of IoT and AI is transforming the landscape of precision agriculture, providing a more sustainable solution to these issues.

With IoT sensors, farmers can keep an eye on environmental factors like soil moisture, temperature, and humidity in real time. For analyzing the patterns from collected data, Convolutional Neural Network helps to predict the humidity level. The predicted value is very important for managing crop and further planning in irrigation.

The proposed framework lays the groundwork for a more comprehensive smart agriculture platform. The main aim of this system is to collaborating farmers with young entrepreneurs by providing reliable and solutions with real-time data. This system can be enhanced with block-chain integration for smart contracts and peer-to-peer agro-market solutions.

Research Methodology

System Design and Architecture

The proposed system is designed with proper structure for efficiency in transferring the data from farming area to AI tool for predicting outcomes. The major components are IoT sensors, middleware system and AI tool for prediction. The sensors, strategically placed in agricultural areas, collect real-time data on important factors like soil moisture, temperature, and humidity. This data is then sent to a backend server via a lightweight JSON API, powered by Flask. Here, MongoDB takes care of storing the information and prepping it for a CNN deep learning model. This system is processed with real-time data for predicting humidity in field that enables users for timely decision-making for managing crops and irrigation. This system also enhanced with dynamic changing in farming area with flexible and fast data communication.

In Figure 1, you can see the layered design of the system. The IoT Layer collects live readings of environmental factors such as temperature, soil moisture, and humidity. This data is transmitted through a RESTful API to a Flask backend, where MongoDB stores it. A CNN-based prediction model then analyzes this information to forecast humidity levels.



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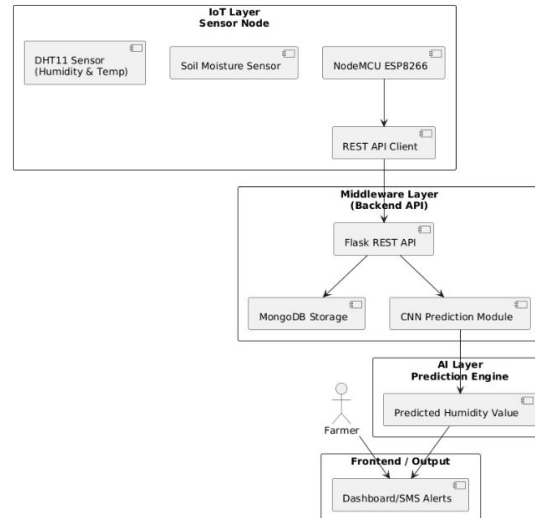


Fig 35.1 System Framework for Data Acquisition and Humidity Prediction

Dataset Preparation

1,200 sensor readings were gathered over 10 days with Celsius degree, percentage of humidity, value of soil moisture along with the time-stamp.

Table 1 shows real-time data collection from the agricultural field using IoT sensors for testing. The sensors recorded data every 30 minutes covering metrics like temperature, humidity, and raw ADC values for soil moisture.

Time-Stamp	Thermal Sensor (°C)	Humidity Sensor (%)	Tensiometer (ADC)
2025-06-11 05:30 AM	28.3	60.9	414
2025-06-12 07:30 AM	29.9	65.0	421
2025-06-14 09:00 AM	30.9	67.1	425
2025-06-15 10:00 AM	31.9	69.0	437
2025-06-16 06:30 AM	34.0	71.1	441

Table 35.1 Outline of Data Acquisition from Agri Field

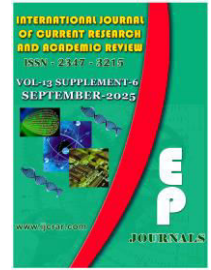


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Below table 2 shows the pre-processed data from the collected data.

Data Stage	Total Records
Raw-Data Collected	1200
Cleaned Records	1150
Normalized Data-set	1150
Training-Set (80%)	960
Testing-Set (20%)	240

Table 35.2 Data Pre-Processing

Data Assessment with CNN

With the help of Tensorflow and Keras, the CNN model was built on Google Colab. It processes three input features – temperature, soil moisture, and prior humidity – and forecasts the next humidity level.

Model Details

- Two Conv1D layers with 32 filters, kernel size 2, and ReLU as the activation function
- One MaxPooling layer
- A single Dropout layer with a 0.25 rate
- Flatten layer connected to Dense layers with 1 neuron in the final output
- Training Loss (MSE) showed a value of 0.0021.
- Validation Loss (MSE) reached 0.0025.

Table 3 shows how the CNN model was evaluated for its performance. The results demonstrate the model's strong ability to handle new sensor data maintaining both high accuracy and fast responses in real-time.

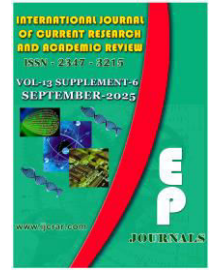


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Metric	Training Set	Testing Set
Mean Squared Error	0.0021	0.0025
Mean Absolute Error	0.039	0.042
R ² Score	0.961	0.945
Prediction Accuracy	96.5%	95.3%
Avg. Latency (ms)	—	470

Table 35.3 Performance Metrics for the CNN Model

Result Analysis

The team tested the system using real-time sensor readings from an agricultural field experiment. They trained a CNN-based model to estimate humidity levels by relying on past data of temperature, humidity, and soil moisture. After deployment, they evaluated results by focusing on how accurate predictions were how well the model generalizes, and how it responds in real time.

Humidity Prediction Performance

The CNN model showed strong prediction skills. It performed well on both training and testing datasets. The R² score for the testing set hit 0.945 showing a high match between actual humidity levels and the model's predictions. The model achieved a mean absolute error (MAE) of 0.042, which is very low even with possible real-world noise.

Real-Time Responsiveness

Quick predictions were important for the system's success. The total delay starting from collecting sensor data to predicting humidity, was about 470 ms.

Comparison Between Models

The below table 4 provides the different prediction from the same data to compare the performance.

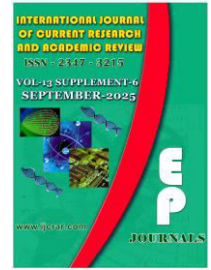


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Model	MAE	MSE	R ² Score	Avg. Prediction Time (ms)
Linear-Regression	0.078	0.0051	0.901	240
Random-Forest	0.059	0.0033	0.921	420
CNN	0.042	0.0023	0.945	120

Table 35.4 Model Comparison to Predict Humidity

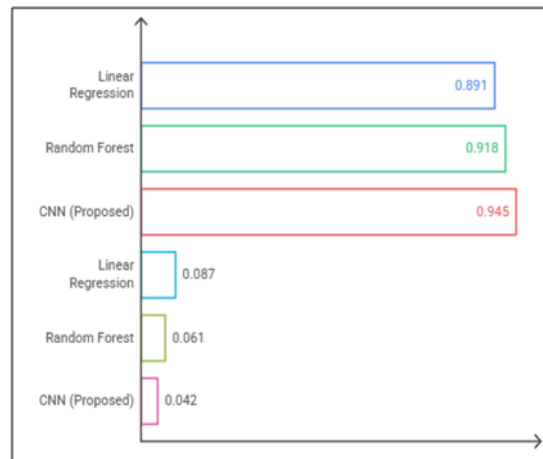


Fig 35.2 R² and MAE Values for Humidity Prediction Using LR, RF & CNN

The above figure 2 depicts the comparison of humidity prediction with other traditional models named linear regression and random forest with proposed model CNN. So, the comparison made up with values of R squared score and mean absolute error values.

- Best accuracy: High R² and Low MAE



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Conclusion

This study proves the scalability and reliability for efficient smart farming with IoT-AI integration for powerful prediction. With continuous monitor of data's like temperature measurements, humidity range, forecasting prediction is accurate. Also, all the collected data's were sent to the backend server using JSON REST API. For the best proving, we compared our data with other models like linear regression and random forest, out of those CNN proves with accuracy R square value is 0.945 and mean absolute value is 0.042. The system we proposed provides a smart, data-driven way for farmers to make well-informed decisions, ultimately boosting productivity and managing resources more effectively. Plus, this research opens the door for future developments that could incorporate blockchain technology for secure and transparent agricultural commerce.

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Full Length Article

IJCRAR/FL/36

Design of Sports Selection Architecture Using Recursive Neural Network and K-Means Clustering Algorithm

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Abstract

Sports are essential part for healthy life for all human being, as it keeps the person fit and agility. Sports also helps person for healthy mind. Practice is very essential for the person in sports. If human body or health is not suitable for the particular sport, then the person cannot lead the sport cycle to the successful part. Selecting the sport is very essential for the success. This paper proposed the system for selecting the correct person to the sports which the person is matched in the boundary of practice and healthy life according to the several perceptions of calculation based speed, weight, height and heart rate. This implementation is developed using MatLab software. This system was implemented with FitRec dataset with the base of Jsion file read with pyspark. For the selection process, this system was designed by Recursive Neural Network (RNN) and for grouping the collected data is completed by K-means clustering algorithm. Result is produced Exploratory Data Analysis (EDA). This system provides the 89% of accuracy rate among the sample size N chosen by the user.

Keywords: FitRec dataset, Jsion, Pyspark, RNN, EDA

Introduction

Sport pertains to the various forms of the competitive in the physical activity that aims to pertain, necessity or improvement fitness that gives happiness to the participants and, but



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perceptions. This paper is explained with complete system of analysis and selection architecture with the design of implementation. As a result, it is best to hire a sports coach to design a customised programme and choose the appropriate sports for the individual based on his or her ability and health, so that the latter does not experience further injuries or negatively impact his or her body's health. And, as we've seen, everybody who engages in sports must understand which sport is ideal for his body and health. [1]

Methods

Data Sources

FitRec Datasets

These datasets contains users sports record on the Endomondo. Data includes many source files of ordered sensors data's like pulse rate, speed, GPS moreover as sports types, user gender and atmospheric phenomenon (i.e. temperature, humidity). After achieving the filters datasets (i.e. endomondoHR_proper.json), the user can able to process the datasets by normalization methods, the measurements data's into Z-Scores. During test, we further strain those users with but 10 workouts. Supports the processing datasets above the normalized version, we use interpolation to get a dataset with same sampling intervals gap of 10s during each and every workout.

Experimental Setup

Measurement data and depending data are collected by using FitRec data set, and these are data are grouped by using K-means clustering based on the grouping as heart rate vs. altitude, heart rate vs. speed, etc. These grouped data are uploaded to the MatLab software for the selection procedure. Selection process is computed by the Recursive Neural Network algorithm.

K-Means Clustering Algorithm

With the help of computation, RNN is utilised to find the right person for the right sport in the FitRec dataset. A RNN is also a method of deep neural network. So, with this, user can expect



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and acquire a structured prediction by applying the identical number of sets of weights on structured inputs. The above algorithm provides the functional data sets value for selection procedure.

1. K is the number of clusters to specify..
2. Shuffling the dataset and picking K data points at random for the centroids without replacing them will initialise the centroids.
3. Continue iterating until the centroid does not change.

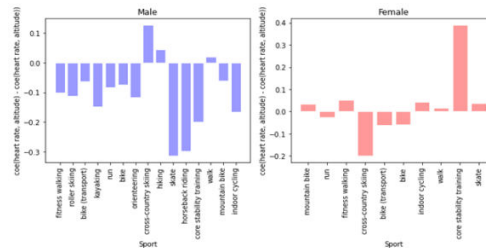


Fig 36.1 Pearson Coefficient Difference Between (Heart Rate, Altitude) vs. (Heart Rate, Speed)

Figure 1 is explained about the clustering structure based on the male and female on the perception of their heart rate, altitude and speed. This system proposed the sports related to the gender wise classification. This system proposed that the male can play more good in cross-country skilling suggested by the Pearson's coefficient calculation resulted as 0.1. Next section, female can be included in the list of sports as mountain bike, run, fitness walk, cross-country skilling, bike race, bike, indoor cycling, core stability training, skate and walk. The selection based on the person's height, weight, speed, state of mind and heart rate. This system proposed that the female can play better in core stability training suggested by the Pearson's coefficient calculation resulted as 0.39.

Recursive Neural Network Algorithm (RNN)

RNN is employed for choosing the acceptable person for the right sports of FitRec dataset with the calculation based. A RNN may be a style of deep neural network. So, with this, user can



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expect and acquire a structured prediction by applying the identical number of sets of weights on structured inputs.

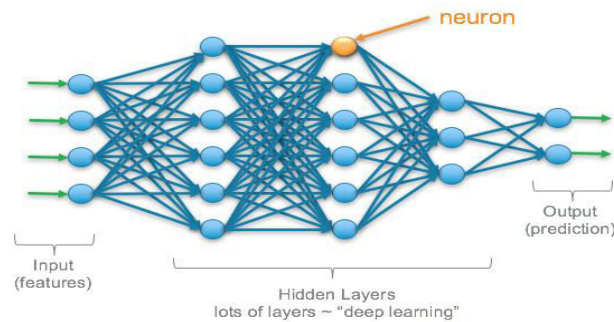


Fig 36.2 An Architecture of RNN

These RNN's are even costlier in any respect computational learning stages and phases.

Step 1: Create a variable to carry the input images as N

Step 2: Set a filter matrix (randomly generate it). With the filter, images are convolved.

$$Z1 = N * f$$

Step 3: On the result, use the Sigmoid activation function. $A = \text{sigmoid}(Z1)$

Step 4: Transform the values with a linear transform. $Z2 = WT.A + b$

Step 5: Run the info through the Sigmoid function. the ultimate product will appear as if this.

$$O = \text{sigmoid}(Z2)$$

There is also differing types of branch that consists of the nodes, but branch nodes of the identical type have tied weights.



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	id	sport	userid	gender	mark	perAvgHeatRate	perAverageAltitude	perAverageSpeed	enegy level	Time taken in mins	Humidity	temperature in F
0	396826535	bike	10921915	male	1	152.650	43.0712	26.162158	50	6	37	98.795355
1	392337038	bike	10921915	male	2	147.710	35.7248	27.218369	40	2	46	98.400333
2	389643739	bike	10921915	male	1	140.554	62.4256	26.050774	68	5	41	98.656770
3	386729739	bike	10921915	male	1	147.020	32.6104	26.877838	42	8	40	98.978446
4	381185226	bike (transport)	10921915	male	1	166.084	13.3640	29.592281	61	10	44	97.093543

Table 36.1 Cleaned and Selected Feature Data

Table 1 states the selection of bike race sports person by the perception based on gender, heart rate, altitude, speed, energy level, time taken, humidity and temperature. This table picks the male gender person as the sports are based on bike race. Each person's average heart rate is approximately from 152 to 167 and average altitude is based on the person's bike. This system is monitored the bike speed of each person and the time taken for completing the task by monitoring each person's body temperature. Average speed is from 26 km/min to 29 km/min and the time taken is between 6 min to 10 min.

Implementing Methodology

JSON File Read In PYSPARK

A JSON dataset's schema can be inferred automatically by Spark SQL and loaded as a Dataset[Row]. This conversion can be performed on a Dataset[String] or a JSON file using SparkSession.read.json(). It's important to note that the json file provided is not a conventional JSON file. Each line must contain a valid JSON object that is self-contained. Set the multiLine parameter to true for a standard multi-line JSON file. The spark.read.json("path") function in SPARK SQL allows you to read a single line or multiline (many lines) JSON file. It's actually rather simple to read the json file; first, establish a SQL Context from the spark context.

Exploratory Data Analysis

The dataset's statistics in terms of total number of sports, workouts, genders, speed, and heart rate are shown in Table 1. Males make up the majority of participants, while females make up the minority, as seen in the table. There are also 17,450 participants of undetermined gender. The speed range is (min = 0.0, max = 148.164 MPH) and the speed mean is (47.783 16.867 MPH).



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The speed standard deviation is low, indicating that the participants' speed values are centred around the mean. The speed rate's minimum value demonstrates that some sports do not necessitate rapid movement. The heart rate range is (min = 0.0, max = 468.0 BPM) and the heart rate mean is (266.14 ± 36.925 BPM). The immense worth of the SD of the pulse shows that the pulse information are dissipated, inferring that the clients' pulses vary altogether. This could be attributable to their orientation, weight, or ailments, among different elements. These distinctions affirm that pulses don't follow a set example and fluctuate starting with one member then onto the next relying upon their singular wellbeing. Accordingly, pulse issues ought to be considered during practices for every individual member; this is the worth of our proposed suggestion framework. Females' pulses are regularly more noteworthy than guys', particularly while skating or taking part in tumbling. All the while, the standards uncover that guys are essentially quicker than females. However, due to athletic heart syndrome, their heart rates are negatively associated with their speed. It's a phenomenon that explains the physiological changes that occur in people who engage in intensive sports training. Finally, our recommendation algorithm will address these two concerns by recommending appropriate sports to participants. Furthermore, during the workout, the participant's heartbeat will be monitored to alert him if his heartbeat crosses a dangerous threshold, allowing him to take appropriate action, such as slowing down or altering his path if there are heights.

Classification Report :									
	precision	recall	f1-score	support		precision	recall	f1-score	support
0	0.52	0.96	0.67	4661	0	0.86	0.98	0.91	4661
1	0.00	0.00	0.00	284	1	0.00	0.00	0.00	284
2	0.00	0.00	0.00	5	2	0.00	0.00	0.00	5
3	0.00	0.00	0.00	7	3	0.00	0.00	0.00	7
4	0.00	0.00	0.00	8	4	0.00	0.00	0.00	8
5	0.00	0.00	0.00	1	5	0.00	0.00	0.00	1
7	0.00	0.00	0.00	201	7	0.00	0.00	0.00	201
8	0.00	0.00	0.00	1	8	0.00	0.00	0.00	1
9	0.00	0.00	0.00	304	9	0.00	0.00	0.00	304
10	0.00	0.00	0.00	1	10	0.00	0.00	0.00	1
11	0.00	0.00	0.00	8	11	0.00	0.00	0.00	8
12	0.00	0.00	0.00	3512	12	0.94	0.99	0.97	3512
13	0.00	0.00	0.00	2	13	0.00	0.00	0.00	2
14	0.00	0.00	0.00	19	14	0.00	0.00	0.00	19
accuracy			0.50	9014	accuracy			0.89	9014
macro avg	0.04	0.07	0.05	9014	macro avg	0.13	0.14	0.13	9014
weighted avg	0.27	0.50	0.35	9014	weighted avg	0.81	0.89	0.85	9014

Table 36.2 Classification Report

Table 36.3 RNN Performance and Accuracy



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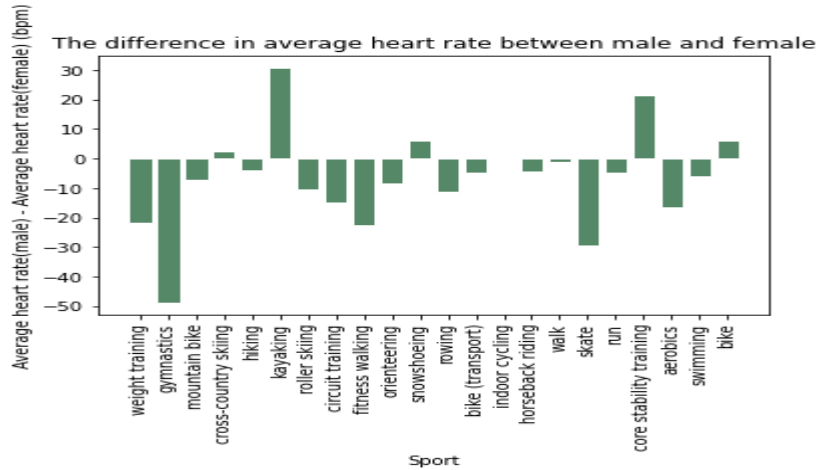
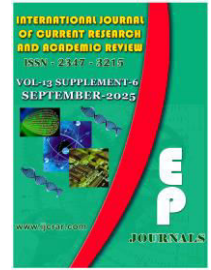


Fig 36.4 EDA Analysis Report – Heart Rate Difference Between Male and Female

Results and Discussion

Based on the comparison, bike race – male can perform -0.04 and female can perform -0.02 and mountain bike – male can perform -0.07 and female can perform 0.02 and skate – male can perform -0.3 and female can perform 0.03 and fitness walking – male can perform -0.1 and female can perform 0.05 and indoor cycling – male can perform -0.13 and female can perform 0.02.

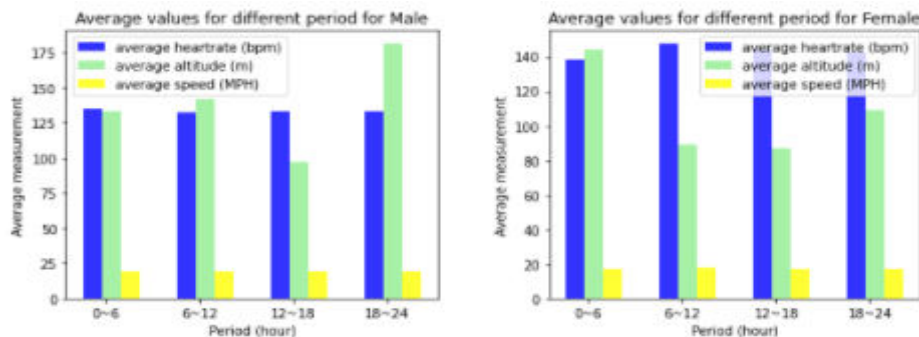


Fig 36.5 Average Value of Heart Rate, Altitude and Speed



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Figure 3 discuss about the total value of the different period of speed, heart rate and altitude for both male and female. On the perception, male can perform with their altitude more in the period of 18 – 24 hours and female can eventually play all the time with normal heart rate.

Conclusion

Sport pertains to any forms of the competition physical activities that aim to using, maintaining or improving the physical strength and the skills while provides joyful to the participants. This paper concludes that the system designed is for selecting the appropriate person to the matched sports under the category that is matched in the boundary of practice and healthy life according to the several perceptions of calculation based speed, weight, height and heart rate. This system was implemented with FitRec dataset and Jsion file read with pyspark. For the selection process, this system was designed by Recursive Neural Network (RNN) and for grouping the collected data is completed by K-means clustering algorithm. Result is produced Exploratory Data Analysis (EDA). This system can result 89% of accuracy precision level is produced by the datasets.

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Full Length Article

IJCRAR/FL/37

A Critical Analysis of Research on Cyberterrorism and the Dark Web in Relation to Terrorism

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Abstract

Cyberterrorism poses a significant threat in today's world. Terrorist groups have found ways to use the dark web to their advantage. They can communicate, recruit new members, raise funds, and plan attacks while remaining hidden. This report analyses the connection between the dark web and terrorism in depth. It explores how cybercrime helps these groups carry out their missions and spread extremist beliefs. The investigation highlights the methods terrorist networks employ to maintain secrecy. Encrypted communication allows them to share information safely. They also use bitcoin transactions as a way to disguise their funding sources. Additionally, the report addresses the use of cyber weapons by these organizations. These tools give them an edge, allowing for attacks on various targets with minimal risk. In response to these threats, intelligence and law enforcement agencies have developed countermeasures. This includes establishing legal frameworks to address cyberterrorism effectively. Infiltration tactics are also used to gather intelligence and disrupt planning. Monitoring dark web activities helps authorities identify potential threats before they escalate. The report seeks to provide a thorough understanding of the relationship between cyberterrorism and the dark web. It reviews existing studies and highlights gaps where more research is needed. By synthesizing this information, the paper aims to present a clearer picture of the ongoing challenges posed by cyberterrorism. It emphasizes the need for continued efforts to combat this pressing issue in our interconnected world.

Keywords: Cyberterrorism, Encrypted, Dark Web

Introduction

Global security has changed as a result of the emergence of digital technologies, which have created new risks that put conventional counterterrorism strategies to the test. Of these



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dangers, cyberterrorism and the dark web have become major issues for academics, law enforcement, and governments. While the dark web offers a covert venue for extremist operations, such as recruiting, funding, and propaganda distribution, cyberterrorism refers to the employment of digital attacks by terrorist organizations to disrupt, threaten, or injure people. The anonymity and decentralized structure of the dark web allow terrorist groups to avoid identification and law enforcement action, even in the face of growing attempts to combat online extremism. This essay evaluates the significance of the dark web and cyberterrorism in contemporary terrorism by critically analyzing the body of research on these topics. Key subjects covered by the paper include the used by terrorist organizations, the efficacy of countermeasures, and the moral and legal difficulties in thwarting cyberterrorist activity. This study aims to give a thorough grasp of the changing digital threat landscape and its consequences for international security by examining academic discussions, case studies, and counterterrorism tactics.

Conceptual Frameworks

The main theories and models that describe how cyberterrorism, the dark web, and contemporary terrorism connect provide the basis of the conceptual framework for this investigation. Understanding how terrorist groups use cyberspace and how counterterrorism initiatives address these risks is made easier with the help of this framework. The following ideas serve as the study's guiding principles:

Theoretical Foundations

Cyberterrorism Theory: This theory examines how terrorist organizations utilize online threats, such as malware, denial-of-service assaults, and hacking, to compromise vital infrastructure, sow fear, and further their ideological objectives.

Routine Activity Theory (RAT): Cyberterrorism flourishes when suitable targets, such as key infrastructure, people, or government institutions, motivated perpetrators, such as terrorist organizations, and a dearth of qualified guardians, such as law enforcement or cybersecurity defences, converge in cyberspace.



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Anonymity and Network Theory: Terrorist organizations can plan attacks, communicate, and raise money while avoiding detection thanks to the dark web's decentralized, encrypted networks.

Counterterrorism and Policy Responses:

Cybersecurity Measures: Government regulations, monitoring systems, and AI-powered counterterrorism tools are examples of cybersecurity measures.

Legal and Ethical Challenges: Fighting online extremism while striking a balance between freedom of speech, privacy rights, and cybersecurity.

International Cooperation: How to combat the threat of cyberterrorism through intelligence sharing, cyber legislation, and international counterterrorism partnerships.

Cyberterrorism: an evolving threat

In the current digital era, where technology is integral to everyday life, governance, and national security, cyberterrorism has become a major worry. Extremist organizations have been able to use digital platforms for recruiting, communication, propaganda, and hacks due to the intersection between terrorism and cyberspace. Cyberterrorism, in contrast to traditional terrorism, uses hacking, data breaches, and digital disturbances to sow panic and fear rather than physical attacks.

Historical Context and Evolution of Cyberterrorism:

The idea of cyberterrorism dates back to the latter half of the 20th century, when the development of the internet opened up new avenues for malevolent activity. Concerns increased in the 1990s when hackers started attacking business and governmental systems, indicating that critical services could be disrupted by cyberattacks. However, rather than organized terrorist organizations, cybercriminals constituted the majority of the early cyber threats.

A change occurred in the early 2000s when terrorist groups began to realize the possibilities of the internet. Online platforms were used by organizations such as Al-Qaeda for recruiting and propaganda. Extremist organizations increased their use of sophisticated



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cyberattacks in the 2010s, including denial-of-service assaults, website defacements, and attempts to compromise vital infrastructure. With the advent of sophisticated encryption, artificial intelligence, and the dark web, cyberterrorism is still evolving today, making it more difficult for law enforcement to detect and stop assaults.

Key Cyberterrorist Groups and Actors:

Numerous terrorist groups have actively participated in cyberterrorism, advancing their goals through the use of digital media. Among the most well-known groups are:

1. ISIS (Islamic State of Iraq and Syria): The Islamic State of Iraq and Syria, or ISIS, is well-known for its widespread use of online propaganda. To recruit new members and disseminate extremist ideas, ISIS has made use of social media, encrypted messaging apps, and the dark web. Additionally, the group has tried to launch cyberattacks against media outlets and governments.
2. Al-Qaeda: Al-Qaeda, one of the first organizations to embrace cyber techniques, has planned attacks, disseminated extremist content, and communicated with its operators all over the world via online forums and encrypted communication.
3. The Syrian Electronic Army (SEA): SEA is a pro-Syrian government hacking group that has carried out cyberattacks against Western media outlets, government websites, and businesses, despite not being a conventional terrorist organization.
4. Lone Wolf Hackers and Cyber Cells: In addition to organized groups, individual hackers and smaller cyber cells have emerged, carrying out attacks in the name of extremist ideologies. These actors often operate anonymously on the dark web, making them difficult to track.
5. Motivations Behind Cyberterrorism:

The motivations of cyberterrorists can be divided into three categories: ideological, political, and economic.

Ideological Motivation: Numerous cyberterrorist organizations aim to radicalize people, sway public opinion, and disseminate extreme ideologies. They can remain anonymous while reaching a worldwide audience thanks to the internet.

Political Motivation: Cyberterrorism is frequently employed to overthrow governments, disturb political order, or exact revenge for perceived wrongs. Cyberattacks are used by some



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organizations to compromise national security, harm vital infrastructure, or reveal sensitive data.

Economic Motivation: Ransomware assaults, internet fraud, and cryptocurrency-based financing of terrorist activities are examples of financially driven cyberterrorism. Cyberterrorists might make money to fund their activities by breaking into financial institutions and stealing data.

The dark web as a facilitator of terrorism:

The dark web is a secret section of the internet that can only be accessed with specialized software, like Tor (The Onion Router). The dark web is a hotbed for illegal activity, including cyberterrorism, because it functions anonymously, in contrast to the surface online, which search engines index. Terrorist groups pose a serious threat to international security efforts by using the dark web for recruiting, communication, funding, and attack planning.

5.1 Structure and Functionality of the Dark Web:

Encrypted networks that anonymize users and their activity form the foundation of the dark web. Its secret services, which are only accessible via particular protocols, guarantee security and privacy. Bitcoin and other cryptocurrencies are frequently used in transactions on the dark web, making it challenging to track down financial flows. In addition to giving terrorists a place to operate outside of the usual observation of law enforcement, this framework facilitates a variety of illicit activities, such as data breaches and the trafficking of weapons.

How Terrorist Organizations Use the Dark Web?

Terrorist organizations use the dark web for a variety of purposes:

- **Secure Communication:** Operatives can cooperate covertly thanks to private forums and encrypted messaging systems.
- **Recruitment and Radicalization:** Dark websites are used to spread extremist propaganda, which draws in new members.
- **Illegal Fundraising:** Terrorists finance their operations through illicit trade, crowdfunding, and cryptocurrency transactions.

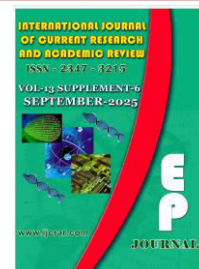


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- Cyberwar fare and Hacking: Cyberattacks against governments and vital infrastructure are made possible by the dark web, which offers access to hacking tools and instruction.

Case Studies of Dark Web Terrorist Activities:

ISIS Propaganda Networks: ISIS has shared operational plans, trained recruits, and disseminated extremist propaganda on the dark web. The organization has been able to evade monitoring on popular social media by using encrypted channels.

Weapon and Explosive Trade: Investigations have revealed dark web marketplaces where terrorist organizations buy weapons, explosives, and chemical substances to use in attacks.

Cryptocurrencies: There have been instances where groups such as Hamas have funded terrorist activities with Bitcoin donations sent through dark web channels.

Methods of Cyberterrorism:

Various digital strategies employed by extremist organizations to compromise security, in still fear, and further their political or ideological objectives are together referred to as cyberterrorism. These techniques take use of flaws in online systems to steal confidential information, harm vital infrastructure, or sway public opinion. The most popular methods employed by cyberterrorists include ransomware, hacking, and disinformation operations.

Hacking and Data Breaches:

Unauthorized access to computer networks, frequently with the goal of stealing, altering, or destroying data, is known as hacking. Hacking is a tactic used by cyberterrorists to gain access to financial institutions, government organizations, and vital infrastructure like transportation or power grids. Terrorists can cause widespread turmoil and disruption by focusing on vital services. An example of how cyberattacks may devastate large corporations is the Shimon virus attack, which targeted Saudi Aramco in 2012 and erased data from thousands of systems.



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Ransomware and Cyber Extortion:

Malware that encrypts data and prevents access until a ransom is paid is known as ransomware. Ransomware attacks are used by cyberterrorists to demand money from people, businesses, and governments. These monies could be used to support radical ideology, buy weapons, or finance terrorist activities.

Disinformation and Propaganda Campaigns:

Spreading inaccurate or misleading information in an effort to sway public opinion, provoke violence, or topple governments is known as a disinformation campaign. Terrorist organizations disseminate material, radicalize people, and enlist followers using social media, encrypted chat services, and the dark web.

Counterterrorism strategies:

Governments, law enforcement organizations, and cybersecurity specialists have put in place a number of tactics to counteract cyber threats as they continue to develop. Government regulations, international collaboration, intelligence collection, and cybersecurity measures are some of these tactics. However, obstacles like the dark web's anonymity and the speed at which technology is developing make counterterrorism activities more difficult.

Government Policies and International Cooperation:

To combat cyberterrorism, governments all over the world have implemented legislative frameworks and strategies. Numerous countries have passed cybersecurity legislation that makes online terrorist acts, such as cyberattacks, the spread of propaganda, and online radicalization, illegal. The USA PATRIOT Act, for example, gave law enforcement organizations more authority to keep an eye on internet communications and stop the funding of terrorism.

Cybersecurity Measures and Intelligence Gathering:

Advanced cybersecurity measures and information collection methods are essential to counterterrorism efforts that work. Tools used by governments and private cybersecurity companies include:



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Intrusion Detection Systems (IDS): Network traffic is monitored by intrusion detection systems (IDS) for indications of cyberattacks.

Machine learning and artificial intelligence (AI): AI-powered systems examine enormous volumes of data to identify questionable activity and anticipate possible dangers. Digital Forensics: To find cybercriminals, follow digital traces, and retrieve encrypted data, law enforcement organizations employ forensic methods.

Cyber Threat Intelligence (CTI): Intelligence organizations gather and examine information about cyber threats, such as dark web activity and terrorist communication trends.

Future Trends and Emerging Threats:

Cyberterrorists' strategies evolve along with technology. Global security faces new difficulties from emerging dangers including deep fake technology, artificial intelligence (AI), and decentralized financial systems. To predict future cyberterrorism threats and create efficient defences, it is essential to comprehend these tendencies.

Advancements in Technology and AI in Cyberterrorism:

Artificial intelligence is emerging as a potent weapon for cyberterrorism and cybersecurity. Terrorist organizations can use AI in a number of ways:

- **Automated Cyberattacks:** Malware driven by AI is quicker than human hackers at locating and taking advantage of system flaws.
- **Deep fake Propaganda:** Videos and audio produced by artificial intelligence (AI) can be used to disseminate false information, sway public opinion, and enlist people in extremist organizations.
- **AI-Enhanced Evasion Tactics:** By evading security measures like facial recognition and CAPTCHA systems, cyberterrorists can employ AI to make detection more challenging.

Drones and Autonomous Weapons: The development of robotics and AI-controlled drones may result in increasingly complex terrorist operations,



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- in which unmanned devices are employed for mass disruptions or targeted killings.

Predicting the Evolution of Terrorist Tactics:

Terrorist organizations are always adjusting to new geopolitical and technological developments. The following are some anticipated advancements in cyberterrorist strategies: Increased Use of the Dark Web and Encrypted Platforms: Cyberterrorists will look for progressively more secure communication channels as monitoring efforts get stronger, and they may eventually use quantum encryption.

Hybrid Cyber-Physical Attacks: Before carrying out physical attacks, terrorists may breach vital infrastructure, such as transportation networks or power grids, in order to blend digital and physical brutality.

Internet of Things (IoT) weaponization: As more smart gadgets are linked to the internet, terrorists may take advantage of security flaws to take over autonomous cars, cause widespread blackouts, or disrupt cities.

The Role of Cryptocurrency in Funding Terrorism:

Because they offer a decentralized and anonymous way to conduct financial transactions, cryptocurrencies like Bitcoin and Monero are appealing to terrorist groups. The following are important facets of cryptocurrency use in terrorism:

Anonymous Fund Transfers: Without depending on conventional financial institutions, cryptocurrencies enable terrorists to move and receive donations.

Dark Web Crowdfunding: To make it harder for government officials to monitor transactions, extremist organizations have turned to dark web portals to raise cryptocurrency donations.

Money Laundering using Crypto Mixers: To make it nearly hard to track down the origins of money, terrorist groups frequently utilize bitcoin mixers, also known as tumblers.

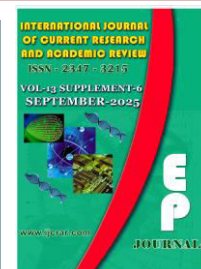


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Conclusion:

The dark web and cyberterrorism have emerged as major threats to contemporary security, giving terrorist groups more efficiency, anonymity, and reach. The dangers of cyberterrorism will only increase as technology develops, making it a major concern for governments, law enforcement, and cybersecurity professionals. The study emphasizes how cyberterrorists use the dark web, ransomware, hacking, and misinformation to recruit people, disrupt societies, and fund their operations. To lessen these risks, governments and international organizations have put counterterrorism measures into place, including cybersecurity regulations, intelligence collection, and technology advancements. However, law enforcement operations are becoming more difficult due to issues like encryption, decentralized online platforms, and the dynamic nature of cyber threats. A multidimensional strategy is required to counter these changing threats, including improved cybersecurity, greater international cooperation, raised public awareness, and ongoing legislative framework adaption. To handle present and future cyberterrorism threats, governments, private sector companies, and cybersecurity specialists must collaborate to create proactive solutions, improve digital forensics, and put countermeasures in place. In the end, even though cyberterrorism cannot be completely eradicated, its effects can be greatly lessened with a well-thought-out and strategic reaction, guaranteeing a more safe online and offline environment.

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Full Length Article

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AI in Healthcare from Diagnostics to Sepsis

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Abstract

Sepsis is a global health challenge, responsible for high morbidity and mortality across healthcare systems worldwide. It is characterized by life-threatening organ dysfunction resulting from a dysregulated host response to infection. Despite advances in medicine, the timely detection and treatment of sepsis remain difficult due to its heterogeneity and rapid progression. Artificial Intelligence (AI) has emerged as a powerful tool to address these challenges by enabling early diagnosis, microbial identification, treatment optimization, and outcome prediction. This paper provides an overview of the applications of AI in sepsis, explores the types of AI models used, and discusses their contributions to reducing mortality and improving patient outcomes. Challenges and future directions are also highlighted, emphasizing the potential of AI to revolutionize sepsis management in modern healthcare.

Keywords: Artificial Intelligence, Sepsis, Machine Learning, Early Diagnosis, Treatment Strategy, Patient Outcomes

Introduction

Sepsis continues to be one of the most critical healthcare challenges, affecting millions annually. According to the World Health Organization (WHO), an estimated 49 million people developed sepsis in 2017, leading to 11 million deaths globally, accounting for nearly 20% of all global deaths. Despite significant investments in healthcare technology, early recognition and effective treatment remain problematic. Traditional approaches to managing sepsis rely heavily on clinical guidelines such as the Surviving Sepsis Campaign, which emphasize early



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administration of antibiotics, fluid resuscitation, and hemodynamic support. However, clinical variability, delayed diagnoses, and difficulty in identifying causative pathogens often hinder timely intervention.

Artificial Intelligence (AI), powered by machine learning (ML), deep learning (DL), and reinforcement learning algorithms, is increasingly applied in healthcare to process vast datasets, identify hidden patterns, and support clinical decision-making.

Literature Review

The integration of Artificial Intelligence (AI) into sepsis management has been studied extensively in recent years, with research focusing on early detection, patient stratification, microbial identification, and treatment optimization. This section reviews key findings from existing literature.

Early Warning and Prediction Models

Early recognition of sepsis is critical, as mortality increases with every hour of delayed treatment. [1] introduced the Artificial Intelligence Sepsis Expert (AISE), an interpretable machine learning model capable of predicting sepsis onset 4-12 hours prior to clinical recognition using real-time ICU data. Their study demonstrated that AI systems can significantly outperform traditional scoring systems such as SOFA and SIRS in predictive accuracy [1]. Commercially, the Epic Sepsis Model (ESM) has been widely implemented in hospitals. However, independent evaluations highlight its limitations. Wong *et al.*, (2021) found that ESM had poor generalizability and low sensitivity, raising concerns about its reliability in diverse patient populations [2]. Recent evaluations also suggest that over-reliance on ESM alerts may lead to alert fatigue among clinicians, reducing its effectiveness in real-world settings [3].

Classification of Sepsis Subtypes

Sepsis is a heterogeneous syndrome, and AI has played a pivotal role in identifying clinically meaningful subtypes. [4] conducted a large-scale study that identified four clinical sepsis phenotypes (α , β , γ , δ), each associated with distinct biomarker profiles, treatment



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responses, and mortality risks. Such stratification enables personalized treatment strategies and has major implications for designing adaptive clinical trials [4]. Recent reviews [5] emphasize that phenotype-based classification, supported by unsupervised machine learning methods, is vital for reducing overtreatment and tailoring precision medicine approaches in sepsis care [5].

Microbial Identification and Antimicrobial Resistance

Traditional culture-based methods for pathogen identification are time-intensive. AI-assisted approaches have accelerated this process by leveraging image recognition, genomics, and natural language processing. Studies demonstrate that deep learning models can classify pathogens from blood smears and predict antimicrobial resistance profiles using genomic data with high accuracy [6]. Such advances can shorten the diagnostic cycle from days to hours, enabling faster initiation of targeted therapies.

Treatment Optimization and Decision Support

Reinforcement learning has emerged as a promising paradigm for optimizing sepsis treatment strategies. Models trained on EHR data have simulated fluid resuscitation and vasopressor dosing policies that mimic or outperform human clinician strategies. While most findings are currently based on retrospective datasets, the potential for adaptive, real-time treatment guidance is strong [7].

Early Warning Systems in Sepsis

Early detection of sepsis is critical because delays in treatment significantly increase the risk of mortality. AI-powered early warning systems integrate electronic health records (EHRs), laboratory values, and continuous vital sign monitoring to predict the onset of sepsis hours before clinical manifestation. Machine Learning Models such as decision trees, random forests, and gradient boosting machines can identify high-risk patients based on subtle changes in parameters like heart rate, respiratory rate, lactate levels, and white blood cell count.

Deep Learning Models including recurrent neural networks (RNNs) and long short-term memory (LSTM) networks process sequential patient data to detect temporal patterns of



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deterioration. For example, the Epic Sepsis Model (ESM) is one widely used commercial system that predicts sepsis risk, though it has also been criticized for lack of transparency and generalizability.

Classification of Sepsis Subtypes

Sepsis is not a single disease entity but a syndrome with multiple phenotypes. Identifying subtypes allows for more precise interventions. Unsupervised Learning Algorithms such as clustering techniques (k-means, hierarchical clustering) analyze EHR data to group patients into distinct sepsis subtypes. Genomic and transcriptomic datasets combined with AI enable the discovery of molecular subtypes that respond differently to treatments.

For instance, research has identified four clinical sepsis subtypes (α , β , γ , δ), each associated with different mortality risks and treatment responses. AI makes such classification possible in near real-time, paving the way for personalized sepsis care.

Microbial Identification

Rapid microbial identification is essential in guiding antibiotic therapy. Traditional cultures are time-consuming, often taking 24–72 hours. AI helps accelerate this process through:

Image Recognition Models: Deep convolutional neural networks (CNNs) can analyze blood smear or culture images to identify bacterial morphology. **Genomic Data Analysis:** AI processes whole-genome sequencing and metagenomic data to detect pathogens and predict antimicrobial resistance. **Natural Language Processing (NLP):** AI can extract relevant microbiology results from unstructured clinical notes, assisting clinicians in decision-making.

Studies show AI can predict antibiotic resistance patterns with high accuracy, supporting early selection of appropriate therapies.

Hypothetical Analysis and Adaptive Treatment Strategies

AI is increasingly used for treatment simulation and optimization.



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Hypothetical Analysis

AI models can simulate the outcomes of different antibiotic regimens, helping clinicians select the most effective therapy while minimizing resistance. For instance, reinforcement learning algorithms model the potential outcomes of choosing one antibiotic over another.

Adaptive Treatment Strategy

Adaptive models go beyond hypothetical scenarios by providing real-time recommendations on:

- IV fluid administration (balancing under- and over-resuscitation).
- Vasopressor selection and dosing for maintaining hemodynamic stability.
- Dynamic antibiotic adjustments based on evolving patient data.
- Reinforcement learning is particularly promising, as it mimics clinician decision-making, learns from patient responses, and continuously adapts treatment plans.

Prediction of Patient Outcomes

AI is also applied in predicting key outcomes such as:

Mortality (Death Rate): Predictive models assess patient risk based on clinical data at admission and during hospitalization.

Inpatient Time: AI estimates the length of stay, enabling better resource allocation and hospital management.

By forecasting patient outcomes, AI can assist in triaging patients, guiding palliative care decisions, and optimizing ICU resource use.

Artificial Intelligence Model Types in Sepsis

Different AI learning approaches play distinct roles:

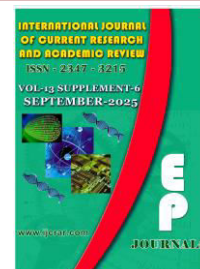


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Partially Supervised Training

Applied when labeled datasets are limited, useful for microbial identification and early warning models.

Self-Supervised Learning

Leverages unlabeled data to create feature representations, suitable for hypothetical treatment analysis and patient monitoring.

Fully guided learning

Relies on structured labeled data, crucial for adaptive treatment recommendations requiring clinical validation.

Reward-Based (Reinforcement) Learning

Focuses on optimizing long-term outcomes (e.g., reducing mortality or ICU stay) by simulating sequential treatment decisions.

Technology Assistance in Clinical Practice

- Implementing AI in sepsis care requires:
- Integration with hospital EHR systems.
- Real-time data processing and interoperability across departments.
- Clinical Decision Support Systems (CDSS) enhanced with explainable AI.
- Training clinicians to interpret AI recommendations effectively.

Challenges and Limitations

Despite its promise, AI in sepsis faces challenges:

1. Data Quality: Incomplete or biased datasets may reduce model accuracy.
2. Transparency: Black-box models lack interpretability, making clinicians hesitant to trust predictions.



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3. Ethical Concerns: Patient privacy and data security must be ensured.
4. Generalizability: Models trained on one population may not perform well on others.
5. Regulatory Barriers: Lack of clear frameworks delays clinical deployment.

Future Directions

Future advancements in AI for sepsis could include:

Hybrid Models: Combining clinical, genomic, and imaging data.

Explainable AI (XAI): Increasing transparency to build clinician trust.

Federated Learning: Allowing hospitals to share model insights without compromising patient privacy.

Wearable Devices: Continuous patient monitoring and real-time AI prediction outside ICU settings.

Conclusion

AI has the potential to transform sepsis management by enabling early detection, subtype classification, microbial identification, adaptive treatments, and outcome prediction. Although challenges remain, the integration of AI into clinical practice could significantly reduce sepsis-related deaths and healthcare costs. With continued innovation, validation, and ethical deployment, AI will become an indispensable tool in modern critical care.

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Full Length Article

IJCRAR/FL/39

A Critical Analysis of Automation in Cloud Computing Environments

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Abstract

This paper presents a comprehensive analysis of automation in cloud computing, focusing on its impact on operational efficiency, scalability, and cost optimization. As cloud infrastructures grow in complexity, the need for intelligent automation becomes increasingly vital. Through the examination of key automation technologies—including Infrastructure as Code (IaC), CI/CD pipelines, and container orchestration platforms—this study evaluates how organizations are leveraging automation to streamline deployment, resource management, and security operations. The paper analyzes the performance, flexibility, and challenges of popular automation tools such as Terraform, Ansible, Kubernetes, and Jenkins across different cloud service models (IaaS, PaaS, SaaS). It also explores case studies from leading technology firms to assess the real-world effectiveness of automated cloud environments. By comparing the benefits and limitations across various implementations, this analysis identifies best practices and strategic considerations for adopting cloud automation. The findings suggest that while automation offers significant advantages, careful planning and expertise are required to mitigate risks and ensure alignment with business objectives.

Keywords: Cloud computing, cloud operations, inefficient, error-prone

Introduction

Cloud computing has revolutionized the way organizations manage and deliver digital services by offering scalable, on-demand access to computing resources. As cloud environments



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grow more dynamic and complex, manual management becomes inefficient, error-prone, and costly. In response to these challenges, automation has emerged as a critical enabler of efficient cloud operations, facilitating everything from infrastructure provisioning to application deployment and system monitoring. Automation in cloud computing refers to the use of software tools and scripts to perform routine cloud management tasks without human intervention. Technologies such as Infrastructure as Code (IaC), Continuous Integration/Continuous Deployment (CI/CD) pipelines, and container orchestration frameworks like Kubernetes have transformed how cloud services are delivered and maintained. These tools not only reduce operational overhead but also enhance consistency, scalability, and reliability.

This paper presents a detailed analysis of automation in cloud computing, examining its practical applications, key technologies, benefits, and limitations. Through the comparison of widely used automation tools and the evaluation of real-world case studies, this study aims to identify how automation contributes to cloud efficiency and what trade-offs organizations must consider. Additionally, the paper explores emerging trends in AI-driven automation and serverless computing, offering insights into the future direction of automated cloud operations. By analyzing both the technological and strategic aspects of automation, this research provides a critical understanding of its role in modern cloud environments and offers recommendations for effective adoption.

Literature Review

The integration of automation in cloud computing has been widely studied over the past decade, as organizations increasingly rely on cloud infrastructure for scalability and flexibility. Early research by Armbrust *et al.*, (2010) laid the groundwork by highlighting the importance of elasticity in cloud environments, which later became a primary driver for automation. Subsequent studies emphasized the role of Infrastructure as Code (IaC) in automating cloud resource provisioning, with tools like Terraform and AWS CloudFormation becoming industry standards (Humble & Farley, 2011). Researchers such as Sharma *et al.*, (2018) explored the impact of Continuous Integration/Continuous Deployment (CI/CD) pipelines in accelerating software delivery within cloud platforms. Similarly, the work of Burns and Oppenheimer (2016)



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on Kubernetes demonstrated how container orchestration enables automated scaling, deployment, and management of cloud-native applications.

While the benefits of automation—such as increased speed, consistency, and reduced manual errors—are well-documented, recent literature also highlights several challenges. Studies by Gupta and Sharma (2020) discuss issues like tool complexity, skill shortages, and integration difficulties with legacy systems. Furthermore, recent papers have begun to explore AI-driven automation, predictive analytics, and self-healing systems as future directions for automation in the cloud (Zhang *et al.*, 2022). Overall, the literature provides a strong foundation for understanding how automation transforms cloud operations, but also points to areas requiring deeper evaluation, especially in terms of security, cost management, and cross-platform integration.

Methodology

This research adopts a **comparative analytical methodology** to evaluate automation tools and technologies in cloud computing. The study focuses on how different automation strategies impact cloud operations in terms of performance, scalability, security, and cost efficiency. The approach includes both qualitative and quantitative aspects, supported by literature reviews, industry case studies, and algorithmic frameworks relevant to cloud automation.

Comparative Evaluation Framework

To systematically assess cloud automation tools, a multi-criteria evaluation model is used. The following parameters form the basis of comparison:

- **Provisioning Efficiency:** Time and accuracy of automated resource provisioning.
- **Integration Flexibility:** Compatibility with major cloud providers (AWS, Azure, GCP).
- **Scalability and Performance:** How tools support auto-scaling and load balancing.
- **Security Automation:** Built-in features for compliance, monitoring, and threat mitigation.
- **Cost Optimization:** Reduction of operational costs via automation.
- **User Adoption and Community Support:** Popularity, documentation, and support channels.



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Tools such as **Terraform**, **Ansible**, **Kubernetes**, **AWS Cloud Formation**, and **Jenkins** are analyzed across these criteria using data from documentation, case studies, and existing performance benchmarks.

Case Study

1. Netflix – Automation for Scalability and Resilience

Industry: Streaming / Media

Cloud Provider: AWS

Key Automation Tools: Spinnaker, Chaos Monkey, Asgard

Automation Goals: Automated deployments, failure recovery, service discovery **Impact:**

- Deployed updates hundreds of times a day
- Resilient architecture with automated failure handling
- Enhanced user experience with minimal downtime

Amazon – Self-Healing Infrastructure at Scale

Industry: E-commerce / Cloud Services

Cloud Provider: AWS (internal + customer services)

Key Automation Practices: Auto-scaling, self-healing, Lambda (serverless automation), Cloud Formation

Automation Goals: Maintain performance under massive traffic spikes **Impact:**

- Fully automated infrastructure provisioning and scaling
- Self-healing services restart or reroute automatically on failure



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- Faster service delivery through CI/CD pipelines

Spotify – CI/CD Automation for Rapid Feature Deployment

Industry: Music Streaming

Cloud Provider: Google Cloud Platform (GCP)

Key Automation Tools: Jenkins, Docker, Kubernetes, Backstage (Spotify-built DevOps tool)

Automation Goals: Speed up software releases and maintain consistency across teams

Impact:

- Dozens of services deployed daily with minimal manual oversight
- Standardized workflows for 100+ developer teams
- Reduced deployment errors and increased delivery speed

NASA – Automated Cloud Data Processing for Earth Observation

Industry: Government / Space Research

Cloud Provider: AWS

Key Automation Tools: AWS Lambda, S3, Step Functions

Automation Goals: Process satellite imagery with minimal human input **Impact:**

- Automated workflows reduced processing time from days to hours
- Server less infrastructure scaled based on data volume
- Lower operational costs with event-driven automation



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Capital One – Security Automation in Financial Cloud Operations

Industry: Banking / Finance

Cloud Provider: AWS

Key Automation Tools: Cloud Custodian, Terraform, Jenkins

Automation Goals: Enforce security policies and automate compliance checks **Impact:**

- Real-time policy enforcement (e.g., shutting down unsecured instances)
- Automated compliance reporting
- Reduced human error in managing sensitive infrastructure

Conclusion

Automation plays a critical role in modern cloud computing by enabling faster, more reliable, and scalable operations. This analysis shows that tools like Terraform, Kubernetes, and Jenkins streamline tasks such as provisioning, deployment, and scaling, while real-world examples from companies like Netflix and Capital One highlight the practical benefits of automation in action. Despite its advantages, automation also presents challenges, including tool complexity, integration issues, and security risks. Addressing these requires proper planning and skilled personnel. Looking ahead, AI-driven automation and serverless architectures are set to further enhance efficiency and resilience in cloud environments. Overall, automation is not just an enhancement but a necessity for organizations aiming to stay competitive in today's digital landscape.

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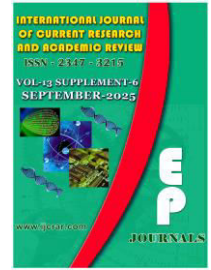


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Full Length Article

IJCRAR/FL/40

Security issues in Cloud Computing

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Abstract

Cloud Computing refers to a broad range of services delivered over the Internet, collectively known as the 'Cloud.' This technology has become one of the most prominent and sought-after solutions in today's world, primarily due to its capacity to lower computing costs while enhancing flexibility and scalability. It's fascinating to note that because cloud computing is such a comprehensive field, different professionals might offer varying definitions, all of which could be valid in their own contexts. However, it's crucial to acknowledge that there are significant data security and privacy concerns associated with cloud computing. In this paper, I will explain what Cloud Computing is, outline the different types of clouds and their models, and underscore the key security issues that must be considered.

Keywords: Cloud computing, Saas, Paas, Iaas, Security issues

Introduction

The term Cloud refers to something that is present everywhere that can be accessed by anyone from any part of the world like Internet, hence the name Cloud Computing. In other words, we can say that Cloud is something which is present at remote location over network. Cloud Computing refers to manipulating, configuring and accessing the applications. As the name suggests, cloud computing refers to something that is ubiquitous and accessible to anybody, wherever in the globe, such as the Internet. Put another way, we can define the cloud



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as anything that exists remotely via a network. Using the cloud (via the Internet) to manipulate, configure, and access applications is known as cloud computing. Both hardware resources and software components are used in cloud computing. Depending on the needs and demands of the users, cloud computing offers them all services like storage (SaaS), infrastructure (IaaS), and platform (PaaS).

To put it simply, cloud computing is the provision of services, such as servers, storage, databases, networking, and software, via the internet (the "cloud"). Pay-as-you-use cloud services offer cost-effective, scalable, and agile solutions. Line through Cloud (over Internet). Cloud Computing has both, the components of software and hardware resources involved in it. Cloud computing provides everything like a service including storage (SaaS), infrastructure (IaaS) and platform (PaaS) for the users as per their requirements and needs. To make it more elaborate we can simply say that Cloud computing is the delivery of services including servers, storage, databases, networking and software over the internet ("Cloud"). Cloud provides services on a pay-as-per use basis offering agile, scalable and cost effective service.

Types of Cloud

- **Public Cloud** -> The public cloud allows systems and services to be easily accessible to the general public on pay-as-per use basis. It allows scalability and resource sharing. Public clouds are owned and operated by the cloud service providers, which deliver their computing resources like servers and storage over the Internet. Microsoft Azure, Amazon Web Services are an example of a public cloud.
- **Private Cloud** -> The private Cloud on the other hand refers to computing resources used exclusively by a single business or organization. Private Cloud can also be said as an internal cloud for a company that can be used only by its members and no other general public can have access to it. Private cloud is a more secure cloud system and has more control over its system as it is used by a selected group of people.
- **Hybrid Cloud** -> Hybrid cloud as the name suggests is a combination of both private cloud and public cloud. It creates a single environment to operate both the private cloud resources as well as public cloud resources there by providing increased flexibility. In simple words we can say that in hybrid cloud, both private and public cloud is integrated providing the features of both in one single frame.



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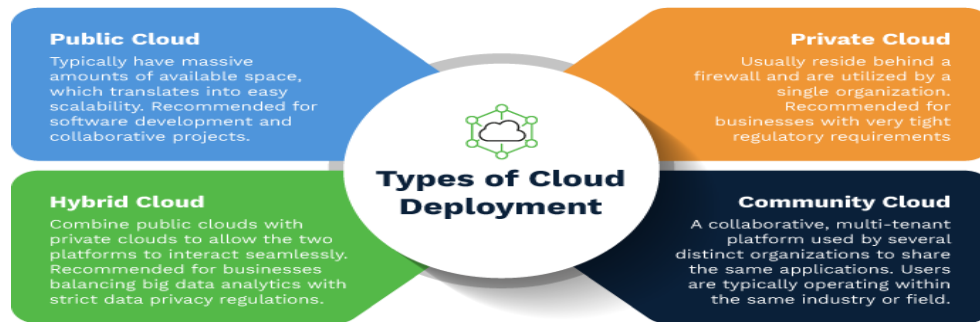
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- Community Cloud->Community cloud computing refers to the one in which a group of several organizations or companies share the cloud services. The organizations having the same concerns can share the resources in community cloud. The services can be hosted by a single or group of organizations belonging to the community or by some external third party as well.



Literature Review

SL.No.	TITLE	AUTHOR	FINDINGS	REMARKS
1.	A comprehensive study on cloud computing	Suruchee V. Nandgaonkar, Prof. A. B. Raut	Motivation factors of adopting cloud computing and reviewing different deployment and service models of cloud. It also explores certain benefits of cloud	In this study I got to know about the cloud architecture. Its deployment or service Models where They are used



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			Computing over traditional IT services including scalability, flexibility etc	and why they are used.
2.	Introduction to Cloud Computing	Prof. Syed Neha Samreen, Prof. NehaKhatrri-Valmik, Prof. Supriya Madhukar Salve, Mr.PathanNouman Khan	What is cloud computing, why to use cloud computing and its architecture is explained.	A brief intro of cloud Computing and the reasons explained to opt for cloud computing.
3.	Cloud Computing Review	VivekPaul, SupriyaPandita, Prof. MeeraRandiva	Cloud computing deployment models and design principles are discussed.	The design of cloud computing is well explained and its benefits also.
4.	Cloud Computing and Saas implementation	Sayali A. Ambavane, Ajay S.Pawar, Vivek H. Verma, PallaviMarathe	Cloud computing characteristics explained. A detail description of Saas implementation is given.	All the deployment models are explained. Saas requirements are well explained.

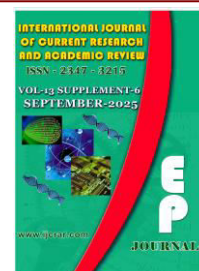


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5.	A Survey on Cloud computing	ShyamPatidar; DheerajRane; Pritesh Jain	The buzz and trend of cloud computing is being talked about in this paper. The various benefits of cc is also explained.	Cloud computing has created a great impact on the tech industry around the world.
6.	Virtualization in Cloud Computing	T.Swathi, K.Srikanth, S. Raghunath	How virtualization plays an important role in cloud computing and its advantages.	Without virtualization cloud computing is inefficient and difficult to use.
7.	Services of cloud computing	Kanusu Srinivasa Rao, Ratnakumari	The services provided by cloud computing including Iaas, Paas, Saas, Naas.	All the services are well explained.
8.	Cloud computing and Security issues in the Cloud.	Monjur Ahmed and Mohammad Ashraf Hossain	Authentication in cloud and various security issues are	Security of data is one of the biggest
			Explained verywell.	concern in cloud computing.

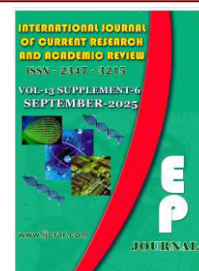


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9.	Datasecurityincloud.	K.S.Wagh ^À , Swapnil Chaudhari ^À , Anita Deshmukh ^À and Prajakta Khandave	This paper also focuses on security issues of cloud.	Data security in cloud is the biggest priority for any user.
10.	Asurvey on security of cloud computing	Varsha Yadav, Preeti Aggarwaal	It focuses on security of cc mentioning some encrypting algorithms.	There are certain encryption algorithms and data partitioning scheme for cloud security.
11.	Cloud Computing- Research Issues, Challenges, Architecture, Platforms and Applications: A Survey	Santosh Kumar and R. H. Goudar	Populer cloud computing platforms and comparison between cloud and grid computing.	This paper Very well explains the issues of cloud computing also explaining security and privacy issue.
12.	Cloud Computing : Research Issues and Implications	M. Rajendra Prasad, Rlaxman Naik	Cloud computing issues and implications are explained along with its basic architectures.	A brief and nice explanation of the security issues are mentioned.

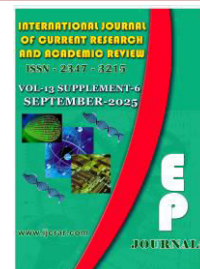


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Models for Cloud Service Delivery

- a) Software that is offered as a service SaaS: SaaS is a cloud service where the entire software is offered as a service via the internet on a pay-per-use basis. To put it simply, this service simplifies our task by enabling us to utilize the software immediately through the internet rather than downloading and then using it. This service can use any software that is available.

Ex-Googleapps, Dropbox

- b) Infrastructure as a Service (IaaS): Hardware as a service is another name for IaaS. Customers can use this service to rent IT infrastructure, including servers, networking, and storage, as needed. The IaaS cloud computing platform lowers costs by removing the requirement for each firm to maintain its IT infrastructure.

Ex-Google compute engine, Digital Ocean

- c) Platform as a platform as a service (PaaS): PaaS is a service in which hardware and software tools are delivered online by a third-party source. Customers can run, manage, test, and debug their apps on this platform. The user can run all of the hardware and software resources on a platform provided by a PaaS provider. PaaS makes it possible to avoid the hassle and cost of purchasing or maintaining software. software.

Ex-Windows Azure, GoogleApp Engine.

Risks to Cloud Computing Security

A Similar to how a coin has two sides, every subject has two sides. We have studied and learned about cloud computing's many benefits and how it has emerged as one of the hottest technologies of our time. However, cloud computing also presents a number of difficulties and problems, the most significant of which are related to security. It is thought to be the largest obstacle to cloud computing's success. Cloud computing presents numerous and significant security challenges. Let us take a quick look at some of the main security concerns with cloud computing.

- i. UNAUTHORISED ACCESS – Unauthorized system access that results in infiltration and data breaches is the other main security concern with cloud computing. The most



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common causes of account hijacking are social engineering, password theft, and phishing attempts. Similar to unlawful access, authorized users' access intended to damage the cloud can likewise be risky. Any external user can easily cause a data breach and compromise cloud security thanks to these access points.

- ii. MISCONFIGURATION - When cloud security controls are improperly set up or left vulnerable, security misconfiguration occurs, endangering our system and data. To put it simply, misconfiguration occurs when resources on public cloud servers are not set up properly, leaving the system vulnerable to intrusions and attacks. One of the most significant and frequently disregarded security vulnerabilities in cloud computing is misconfiguration. Because of cloud misconfiguration, the majority of businesses are concerned about security.
- iii. DATA LEAKAGE- Data sharing has been a simple process since the advent of cloud computing. However, many businesses are also quite concerned about data sharing because of the potential of data leaks, which is particularly high when it comes to sensitive and crucial business data. Since cloud computing is a multi-user environment that also incorporates third-party users, data leakage is a possibility. This means that anyone, anywhere, can view the data.
- iv. INSECURE API'S-Application programming interfaces (APIs) facilitate the operation of cloud computing operations; if they are not secured, they might give hackers the chance to compromise the system and take advantage of sensitive personal information. Since every company now makes its interfaces available to the public for business partners to access, cloud APIs have become a prime target for attackers. This means that the data is readily available online and can be exploited in any way.
- v. LACK OF VISIBILITY/CONTROL - The organization or user who uses cloud services loses control over the data and has less visibility after they store all of their data there or give the cloud system provider permission to handle or maintain their data. They are no longer able to monitor their data and are unable to confirm their security measures. After utilizing cloud services, a business may encounter a number of additional problems in addition to these. Protecting data and resources from security breaches and cyber threats is made more challenging when there is a lack of transparency and control over them.
- vi. DISTRIBUTED DENIAL OF SERVICE ATTACKS - i. A cloud-specific attack that impacts every cloud layer is DDoS. Multiple machines target a single system or user in this type of assault by sending a lot of data packets, filling the network with undesired



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traffic and preventing the user from using their resources. Both the system and the organizations who use it are impacted by this attack since they are unable to access their data. Because cloud data is shared online, it is vulnerable to virus infestations and cyberattacks.

Conclusion

To sum up, cloud computing is the newest and most sophisticated technology with the potential to offer enormous advantages, but there are still some issues that need to be investigated, such as security and privacy concerns in cloud computing, which many experts have yet to address. The reality is that cloud computing is the next major development in the IT sector, but it still has a long way to go. All of its security flaws will soon be fixed thanks to the efforts of major IT behemoths like Google and Microsoft. Cloud computing has already generated a lot of buzz among consumers, businesses, and organizations of all sizes, and it will soon be embraced by everyone on the planet. Even while it may have some problems, there is no denying that cloud computing has ushered in a new age for the IT sector. It is still in its early stages of development, and there is still a great deal of untapped potential.

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Full Length Article

IJCRAR/FL/41

Artificial Intelligence - Transformation of The Chennai Business Environment

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Abstract

Artificial Intelligence (AI) is reshaping global business by enhancing operational efficiency, data-driven decision-making, and customer engagement through automation, machine learning, and advanced analytics. Globally, AI is projected to contribute up to USD 35 trillion to the economy by 2030, yet it also presents challenges such as workforce displacement and ethical dilemmas. In the Chennai region, AI adoption is still emerging, with gradual integration observed in banking, insurance, IT services, and manufacturing sectors. Existing studies suggest moderate readiness, hindered by skill shortages, inadequate infrastructure, and regulatory constraints. Notable use cases include AI-powered chat bots in banking and micro insurance innovations promoting financial inclusion in peri-urban areas. Although India's National AI Strategy outlines promising directions, local implementation in Chennai requires concrete strategies. Sustainable AI adoption in the Chennai region will depend on strategic policy interventions, capacity-building efforts, and robust ethical frameworks. Striking a balance between technological innovation and social responsibility is critical for Chennai's success in the AI-driven future.

Keywords: Artificial intelligence, digital transformation, ethical frameworks, sustainable adoption.

Introduction

The application of artificial intelligence (AI) to enhance decision-making processes has become increasingly critical in the era of big data, serving as a catalyst for both theoretical advancement and practical implementation.



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While extant research provides valuable insights into contemporary developments within business analytics and AI, the prevailing literature often remains narrowly focused on specific applications—such as Business Intelligence & Analytics (BI&A) or decision support systems—or confined to particular industrial domains. This study aims to address this lacuna in the scholarly discourse by presenting a comprehensive overview of current research on AI in business. This objective will be accomplished through a systematic examination of the field's historical evolution and a synthesis of state-of-the-art research, culminating in the projection of future trajectories. The ensuing analysis is intended to yield a robust conceptual framework and propose fruitful avenues for subsequent scholarly inquiry.

AI- in chennai market

Chennai has emerged as a significant contributor to the global artificial intelligence ecosystem, marked by a dynamic convergence of technological expertise, corporate investment, and entrepreneurial innovation. The city's thriving AI landscape is characterized by robust collaboration between global IT leaders and agile startups, driving progress in automation, predictive analytics, natural language processing, and computer vision. These advancements are being deployed across vital sectors—including healthcare, finance, manufacturing, and retail—delivering tailored solutions that enhance productivity, streamline decision-making, and support comprehensive digital transformation. Leading multinational firms such as Cognizant and Infosys maintain substantial AI research and development operations within the city, while specialized enterprises like Nimblebox.ai, Botminds.ai, and MadStreetDen develop cutting-edge platforms for applications ranging from AI model management and intelligent document processing to contextual data interpretation. This vibrant technological environment enables Chennai to serve a diverse client base, from large enterprises to growing startups, offering scalable SaaS products, bespoke AI development, and end-to-end data services that reinforce its standing as a critical hub in the international technology landscape. Despite these strengths, the city—like other high-growth technology regions—faces challenges related to AI integration, including the need for continuous talent development, ethical governance, and infrastructural scalability. Sustaining this growth will require ongoing investment in education, industry-academia collaboration, and regulatory frameworks designed to foster innovation while mitigating risks.



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With its strong foundation and forward-looking ecosystem, Chennai is well-positioned to not only advance its own technological capabilities but also to play an influential role in shaping the future of AI both nationally and globally.

AI- Baking Industry in India

Artificial Intelligence (AI) is significantly transforming Chennai's banking sector by enhancing operational efficiency, strengthening security protocols, and elevating customer experience. As a major financial hub in India, Chennai has embraced AI-driven innovations to automate processes, detect and prevent fraud, and facilitate data-informed decision-making.

While the pace of adoption varies across institutions, both established banks and emerging fintech companies in the city are increasingly integrating AI technologies to maintain competitiveness and drive digital transformation. Research by Shrestha et al. (2022) highlighted the effectiveness of AI-powered chatbots in improving customer engagement and service delivery. These chatbots, which employ natural language processing to simulate human-like interactions, are being deployed by Chennai-based banks to handle routine inquiries, provide real-time support, and manage high volumes of customer interactions simultaneously. As consumer preference for digital banking grows, such tools play a crucial role in enhancing accessibility and responsiveness. Further studies, including those by Gurung and Parajuli (2024), reinforce that AI chatbots not only meet rising customer expectations but also contribute to overall service quality and organizational productivity. Khadka et al. (2024) emphasized the role of AI and social innovation in reinforcing strategic decision-making frameworks within banking and financial institutions (BFIs), a trend clearly reflected in Chennai's evolving banking landscape. Despite these advancements, challenges such as legacy system integration, data security concerns, and a shortage of specialized AI talent remain. However, supportive regulatory guidance from institutions like the Reserve Bank of India (RBI) and a strong IT ecosystem position Chennai favorably for accelerated AI adoption. With continued investment in technological infrastructure and skill development, Chennai is poised to emerge as a leader in AI-enabled banking innovation.



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AI in the Indian Insurance Sector

An AI-driven micro-insurance initiative in rural India demonstrates how artificial intelligence can enhance financial inclusion by offering affordable and accessible insurance coverage to farmers and small businesses. By leveraging alternative data sources—such as mobile usage patterns, satellite imagery of agricultural land, weather data, and digital transaction histories.

AI systems automate risk assessment and generate personalized policy recommendations. This approach not only expands insurance access to previously underserved communities but also facilitates linkages with credit facilities, helping protect vulnerable populations from climate, economic, and health-related uncertainties. Such innovations underscore the potential of AI to extend insurance outreach across India's diverse and often remote regions, thereby promoting economic resilience and inclusive growth. However, the scalability and long-term success of these initiatives depend on the ethical deployment of AI, stringent data privacy safeguards, and alignment with regulatory frameworks set forth by bodies such as the Insurance Regulatory and Development Authority of India (IRDAI). Building trust through transparency, fairness, and customer-centric design will be essential to sustaining growth and deepening the impact of AI in India's rapidly evolving insurance sector.

AI in the Hydropower Sector

Chennai's growing technology ecosystem is increasingly intersecting with the renewable energy sector, offering innovative solutions to enhance the efficiency and sustainability of power generation. While the region is not traditionally known for large-scale hydropower, the application of artificial intelligence (AI) in energy infrastructure—including small-scale hydro, wind, and solar projects—is gaining traction. AI supports critical functions such as predictive maintenance, energy output forecasting, and optimization of plant operations, helping to reduce costs and improve reliability. In particular, AI-driven analytics can assist in the design and monitoring of energy systems, identifying potential inefficiencies and mitigating risks such as equipment wear and environmental variability. Research by Kumar and Saini (2021) highlights how AI can improve the accuracy of feasibility assessments and support long-term operational planning, including erosion and cavitation management in hydro-mechanical components.



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These capabilities are especially valuable in a diversifying energy market like Chennai's, where integrating renewable sources into the urban grid is becoming a priority.

Although AI adoption in the energy sector is still emerging in the region, Chennai's strong IT expertise, presence of specialized AI firms, and collaboration between academic and industry stakeholders create a conducive environment for innovation. With continued investment and interdisciplinary cooperation, AI has the potential to significantly modernize energy infrastructure—not only in hydropower but across renewable sources—supporting Chennai's transition toward a more sustainable and technologically advanced energy future.

Conclusion

Artificial Intelligence stands as a transformative force within Chennai's business environment, driving innovation across key sectors such as banking, insurance, IT, manufacturing, and renewable energy. The city has demonstrated a growing capacity to integrate AI technologies—enhancing operational efficiency, enabling data-driven decision-making, and expanding services to underserved communities. However, the pace and breadth of adoption remain uneven, constrained by infrastructural limitations, skill gaps, and regulatory challenges.

For Chennai to fully harness AI's potential, a coordinated effort involving policymakers, academic institutions, and industry leaders is essential. Strategic investments in AI education and training, modernized digital infrastructure, and clear ethical guidelines will be critical to fostering a sustainable AI ecosystem. Moreover, cross-sector collaboration can accelerate innovation while ensuring that AI deployment is inclusive, fair, and aligned with broader social and economic goals. As Chennai continues to evolve as a technology hub, its ability to balance innovation with responsibility will determine its competitiveness on both national and global stages.

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Full Length Article

IJCRAR/FL/42

Privacy-Preserving Big Data Analytics With Blockchain and AI

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Abstract

The rapid growth of digital data in domains such as healthcare, finance, and governance has positioned big data analytics as a key driver of innovation and decision-making. However, the increasing use of massive datasets presents major challenges related to security, privacy, and ethical data handling. Traditional big data frameworks, though powerful, often face limitations in transparency, trust, and compliance with global data protection regulations. To address these concerns, this paper proposes an integrated framework that combines Blockchain technology with Artificial Intelligence (AI) for privacy-preserving big data analytics. Blockchain ensures decentralization, immutability, and auditability, providing a secure and transparent environment for data storage and sharing. It reduces reliance on centralized authorities while safeguarding integrity and access control. In parallel, AI techniques such as machine learning and deep learning enable advanced analytics, including predictive modeling and anomaly detection, over large-scale datasets. Together, these technologies create a framework that balances data confidentiality with efficient and intelligent analysis. The proposed approach has broad practical applications. In healthcare, it allows secure analysis of patient records for early diagnosis and research. In finance, it improves fraud detection and risk prediction without compromising client confidentiality. For smart cities and IoT-driven systems, it supports real-time decision-making while preserving citizen privacy. Importantly, the framework also aligns with regulations such as GDPR, ensuring ethical and responsible data use. This study highlights how the convergence of blockchain and AI can build a secure, scalable, and trustworthy ecosystem for big data analytics, enabling organizations to harness data responsibly.

Keywords: Big Data Analytics, Blockchain, Artificial Intelligence, Privacy Preservation, Data Security

Introduction

Big data has emerged as a transformative technology that powers decision-making and innovation in numerous industries, ranging from healthcare and financial services to e-

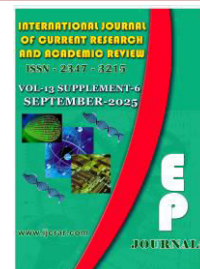


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commerce, governance, and smart cities. The defining characteristics of big data—volume, velocity, variety, veracity, and value—make it both powerful and challenging. While organizations leverage big data for predictive analytics, personalization, and optimization, the increasing reliance on sensitive information has created concerns around privacy, security, and ethical data use.

For instance, patient health records in the medical domain or transaction details in financial systems must be protected against breaches, unauthorized access, and misuse. Traditional big data frameworks, despite their computational efficiency, often lack mechanisms for ensuring data confidentiality and compliance with global regulations such as GDPR and HIPAA. As a result, researchers are exploring novel approaches that integrate security-by-design into data analytics.

Blockchain and Artificial Intelligence (AI) are two disruptive technologies that can address these concerns. Blockchain introduces trust, immutability, and decentralization, while AI enhances big data analytics by providing predictive intelligence and anomaly detection. This paper proposes a combined framework where blockchain provides secure and transparent data management, and AI ensures meaningful analytics without compromising privacy.

Literature Review

Big data has emerged as a transformative technology that powers decision-making and innovation in numerous industries, ranging from healthcare and financial services to e-commerce, governance, and smart cities. The defining characteristics of big data—volume, velocity, variety, veracity, and value—make it both powerful and challenging. While organizations leverage big data for predictive analytics, personalization, and optimization, the increasing reliance on sensitive information has created concerns around privacy, security, and ethical data use. For instance, patient health records in the medical domain or transaction details in financial systems must be protected against breaches, unauthorized access, and misuse. Traditional big data frameworks, despite their computational efficiency, often lack mechanisms for ensuring data confidentiality and compliance with global regulations such as GDPR and HIPAA. As a result, researchers are exploring novel approaches that integrate security-by-design into data analytics.



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Blockchain and Artificial Intelligence (AI) are two disruptive technologies that can address these concerns. Blockchain introduces trust, immutability, and decentralization, while AI enhances big data analytics by providing predictive intelligence and anomaly detection. This paper proposes a combined framework where blockchain provides secure and transparent data management, and AI ensures meaningful analytics without compromising privacy.

Proposed Framework

The proposed privacy-preserving big data analytics framework integrates blockchain and AI in a layered architecture:

1. Blockchain Layer: Responsible for decentralized storage, identity management, and access control. Every transaction is recorded immutably, ensuring transparency and eliminating reliance on a central authority.
2. AI Layer: Includes machine learning and deep learning models for predictive analytics, anomaly detection, and decision-making. AI operates on encrypted or masked datasets, ensuring no sensitive information is exposed.
3. Privacy Mechanisms: Incorporates homomorphic encryption, differential privacy, and secure multiparty computation to safeguard individual-level data while allowing aggregate analytics.

The architecture where raw data flows from collection sources into blockchain-secured storage, followed by AI-driven analytics. This layered approach enables both security and intelligence in data use.

Applications

The framework has diverse applications:

- Healthcare: Enables collaborative research and predictive diagnosis without compromising patient confidentiality.
- Finance: Enhances fraud detection and risk management using AI models while blockchain secures client transactions.



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- Smart Cities: Supports efficient resource allocation, traffic optimization, and citizen services with privacy safeguards.
- Governance: Facilitates transparent public record-keeping and secure digital identities.

By addressing privacy and security challenges, the framework enables responsible digital transformation.

Challenges and Future Directions:

Despite its advantages, the proposed framework faces significant challenges. Scalability is a major issue, as blockchain networks struggle with large-scale data throughput. Interoperability across heterogeneous systems also remains a challenge. Additionally, blockchain's energy consumption and AI's susceptibility to bias raise sustainability and ethical concerns.

Future research should focus on:

- Developing lightweight blockchain protocols for faster transactions.
- Integrating federated learning to train models without centralizing data.
- Exploring quantum-resistant cryptography for enhanced security.
- Ensuring fairness and accountability in AI-driven decision-making.

These directions will ensure the framework remains scalable, ethical, and adaptable to evolving needs.

Conclusion

This paper presents a comprehensive framework that integrates blockchain and AI for privacy-preserving big data analytics. Blockchain provides decentralization and immutability, while AI offers intelligent and predictive analysis. Together, they enable industries to leverage big data responsibly while ensuring compliance with privacy regulations. By addressing scalability, energy efficiency, and ethical concerns, future advancements can transform this approach into a robust solution for secure, transparent, and intelligent analytics.



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Full Length Article

IJCRAR/FL/43

A Comparative Analysis of Machine Learning Classifier Algorithms for Predicting Fake News

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Abstract

There are many records on the Internet that are comparatively valuable for special circumstances. One should exercise caution when it comes to originality because of the abundance of material available online. Social media is a crucial tool for connecting with friends, family, and other individuals. Each user shares information or emotions in many formats, such as text, audio, or video. False information is carefully produced and spreads over the internet either intentionally or unexpectedly. Whether it's true or fraudulent, the amount of data created and consumed online has increased over time. As a result, it has an effect on businesses in society that use the internet extensively and are oblivious to technology. Some people post false information on social media in an attempt to attract attention or to further their political and financial interests. We must become more adept at differentiating between fake and authentic news. Modern detection algorithms are inadequate or inappropriate due to the unique purpose of identifying fake news on social media. Therefore, this work's primary objective is to suggest a comparative analysis of various classifier algorithms and to provide an analysis of various classifier assessment criteria.

Keywords: Fake Information, Social, Networking Analysis, KNN, LSTM, SVM, Naïve Bayes, Random Forest, CNN

Introduction

Due to the rise in active social media users and the amount of unmonitored content being posted, the demand for false news identification has increased dramatically in recent years.



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Regulators must exercise caution and eliminate content that disseminates unnecessary messages. These messages can have a significant impact on others in a variety of sectors, including politics, medicine, technology, and many more. Given the volume of data being produced on social media at the moment, it is imperative to make the most of technology in order to save time and money while also accurately identifying bogus news. Researchers working to eradicate bogus news on social media have mostly employed machine learning and deep learning algorithms. The goal of this paper is to examine every technique currently used to identify fake news. In order to detect phony tweets, [1] compares several machine learning techniques and comes to the conclusion that deep learning models have a wider range than machine learning models. [2] offers a Support Vector Machine-based multiclass classifier on news data that achieves a flawless 100% accuracy rate.

Suggests a score-based multi-source fake news detection framework that, when paired with Gradient Boost, creates an ensemble classifier that can almost perfectly determine the reliability of news sources, with an accuracy of 99.5 percent. [3] compares machine learning methods using official medical papers from several Thai hospitals and demonstrates that XGBoost has the highest classification accuracy.

One of the main fields that has expanded with the introduction of natural language processing models is rumor detection. [4] suggests a KNN classifier that leverages user implicit and explicit information to identify bogus news on social media. [5] In order to identify bogus news, compares different machine learning classifiers and feature extraction techniques. The SVM linear classifier with TF-IDF feature extraction is shown to produce the best results when the models are compared based on accuracy scores and time complexity. [6] identifies phony Twitter profiles by comparing machine learning algorithms including Support Vector Machines, Decision Trees, and Logistic Regression. The best effective classifier was found to be logistic regression. [7] outlines a rumor detection investigation that demonstrated the speed and accuracy of graph-based algorithms when applied to a software system with a high response time. [8] demonstrates how applying the SIWIsRM rumor spreading model to significant social networks helps to greatly grasp the mechanics of rumor propagation. Effective control techniques may also benefit from this. [9] demonstrates a cutting-edge stochastic Attention CNN Model for classifying rumor stances, attaining 78.68% accuracy on the PHEME dataset. [10] explains how to forecast rumor retweeting behavior using a Convolution Neural Network



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model. Since it's crucial to avoid spreading misinformation during emergencies, factors like tweet frequency and reaction time are taken into consideration, making accurate predictions crucial in this situation. The accuracy rate of the model is 88 percent. [11] suggests a three-section method for detecting fake news by employing an ensemble classifier that combines Naive Bayes, Support Vector Machine, and semantic analysis. The accuracy of the binary classifier suggested in this study was 93.50 percent. [12] compares a few different deep learning models and six machine learning methods for identifying fake news using different kinds of data sources. Modified LSTM was the suggested method for classifying fake news when it was shown that deep learning models performed better than machine learning models. [13] provides a comparison of multi-head and bidirectional LSTM to determine the reliability of news articles. [14] introduces a model that combines two CNN models using the embedding technique. The features with the highest accuracy, 96%, were found to be text and author.

There is a lot of research that is developing as a result of the technology developments in natural language processing and the growing awareness and significance of identifying fake news. This essay will provide a thorough analysis of the various studies that have been conducted in this area.

Fake News Detection Using Machine Learning Classifiers

Single Classifier

[1] examines several machine learning techniques for identifying created and fraudulent news. The limitations of these methods are also examined, as is improvisation through the use of deep learning. The authors used DMOZ and the Twitter API to manually acquire data sets. The algorithms listed below were applied. 1. Bayes Naïve 2. Trees of decisions 3. SVM 4. Networks of neurons 5. Forest of Random 6. The XG Boost. According to the results, 15% of tweets were fraudulent, 45% were legitimate, and the other postings were left uncategorized.

Many studies are being conducted to apply deep learning techniques, such as Convolutional Neural Networks, Deep Boltzmann Machines, Deep Neural Networks, and Deep Autoencoder models, in a variety of applications, including computer vision, information



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retrieval, objective recognition, audio and speech processing, and natural language processing and modeling. This is due to the recent implementation of deep learning research and applications. It is also frequently employed in multimodal and multi-task learning for news post classification.

[2] makes use of a news dataset in which news features are divided into three groups: numerical, categorical, and textual. Preprocessing is carried out using a series of procedures in each category. This study merges two existing datasets: "All the news" with actual news and "Getting Real about Fake News" with fake news.

These datasets were sourced from the Kaggle website. The first one uses the webhose.io API to extract text and metadata from 244 websites that Daniel Sieradski's BS Detector Chrome detector identified as bogus. There are roughly 12,999 social media postings in this dataset, which are organized into 20 columns of various kinds, including text, numeric, and category entries.

[3] The second dataset, which was obtained using Beautiful Soup and stored in Sqlite as three distinct CSV files, includes texts and metadata extracted from the New York Times, Breitbart, CNN, Business Insider, Atlantic, Fox News, Talking Points Memo, BuzzFeed News, National Review, New York Post, The Guardian, NPR, Reuters, Vox, and the Washington Post.

[4] Ten columns of various categories, including textual, numeric, and categorical, make up this final dataset, which also includes metadata and texts. The suggested solution accepts a dataset of comments together with the date, source, and author of each remark as input. The Support Vector Machine has been found to offer 100% accuracy.

[5] Suggests a method for classifying data that uses the Gradient Boosting classifier as a kind of Ensemble boosting. A news article from a certain source is considered phony if both its credibility score and its content are confirmed to be authentic (true) or non-credible (false). There are 2050 news items classified as true or fraudulent in the experimental dataset that was gathered from Kaggle.com. In comparison to previous classifiers, the suggested framework and Gradient Boosting classifier produce an impressive accuracy of almost 99.5%.



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High precision, recall, and F1 score of roughly 1.00, 0.99, and 0.99, respectively, are attained with gradient boosting. A brand-new framework for score-based multisource fake news detection has been developed. The TF-IDF technique was used to extract the news articles' top authentic and bogus elements. The believability score of the sources is assessed using the Site_url feature that was acquired from the source. To determine the news's dependability, the Credibility Score of many sources and the collected text-based elements were combined. The suggested framework's viability and efficacy are assessed and contrasted with the various classifiers.

A total of 297 genuine articles from reputable sources, including the official websites of Sukhumvit Hospital, Ramathibodi Hospital, and the Medical Faculty of Mahidol University, Thailand, were gathered for the reliability check model shown in [5]. Using Zhang and Ghorbini's method, 235 untrustworthy articles were gathered from websites that were not expertly moderated and articles from untrustworthy sources like dokkaew.wordpress.com, bamgpunsara.com, colonocancerzone.com, and eatonlinehealth.com.

With an accuracy of 90.60%, XGBoost was the most accurate model. To categorize the dependability or unreliability of medical publications, classification methods such as XGBoost, Decision Tree, k-Nearest Neighbors, Support Vector Machine, and Logistic Regression were employed. XGBoost was the most accurate classification model, according to the classification output.

[6] Detects phony profiles using the K-Nearest Neighbor classification technique. Users' explicit and implicit characteristics are gathered and examined. Explicit features are those that are derived straight from the metadata that social media site API queries return. Unlike explicit features, which include information about whether or not the user was verified, favor count (the number of people who liked that post), follower count, share count, and comment count (the number of people who commented on a post), implicit features are inaccessible because they only include basic information like gender, age, and personality. A maximum classification accuracy of 79% was attained with this method. Suggests classifying data using feature extraction methods and several machine learning classifiers. Datasets gathered from Kaggle are used to guide the text collection process. 244 websites have had their data extracted. It includes



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almost 13,000 posts over a 30-day period. where 9149 is the testing data set and 18574 post is the training data set.

Three distinct feature extraction techniques, including Word Embedding, Count Vectorizer, and TF-IDF Vectorizer, have been applied in this suggested system. The SVM Linear classification approach using TF-IDF feature extraction yielded the highest accuracy of any classification algorithm, with an accuracy of 0.94.

Neural networks can be more complex and take longer to train, even though they achieve the same accuracy when using a count vectorizer. Therefore, Linear SVM, which is less complicated and requires less computation time, is taken into consideration in our suggested system.

[7] Machine learning techniques were employed to identify fraudulent accounts that might deceive users. The created dataset was pre-processed for this purpose, and machine learning methods were used to identify phony accounts. Algorithms such as logistic regression, decision trees, and support vector machines are employed to identify fraudulent accounts. When these methods' classification performances were evaluated, logistic regression turned out to be the most effective.

[8] suggested techniques to identify rumors spreading on social media. The 72 rumors in the dataset were manually found by searching for terms associated with particular events in messages (tweets) gathered from Twitter using the Twitter public API. Every message was personally marked as either neutral/questioning, against, or supportive of the related rumor.

Seven rumors from the 2011 London riots make up the dataset. The dataset has been anonymized, so its features—the 1,000 Brown clusters and the bag of words—replace the communications. The suggested approach was contrasted with supervised and semi-supervised Gaussian processes. The findings demonstrate that graph-based algorithms are more efficient for use in rapid-response software systems since they are quicker and at least as accurate, especially as more annotated messages become accessible.



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[9] Considering the impact of several elements on the transmission of rumors, developed the SIwIsR-M rumor spreading model. The suggested model can be used on large social networks, which can help individuals comprehend how rumors spread and offer theoretical direction for creating efficient control measures.

[10] uses the PHEME dataset, which comprises eight distinct subjects, to classify rumor stances. Several techniques, including Turing (the SemEval 2017 Task 8.A winner), CRF, GP, HP, and a basic LSTM-based classifier, are used to compare the test results. To complete the rumor stance classification task on the PHEME dataset, a SACNN model is suggested. According to the theory of BLSs and ELMS, the CNN's training quality is enhanced by the stochastic attention mechanism. The micro average of eight events is the end result of independently calculating each evaluation indicator on the PHEME dataset based on each event. With an accuracy of 78.68, the model reaches the state-of-the-art values for the Accuracy indicator.

[11] The R-CNN model, which is based on convolutional neural networks (CNN), is a model for forecasting rumor retweeting behavior that is presented in this research. Four feature vectors are constructed using the historical textual content published by users, and they include attention to public emergencies, attention to rumors, reaction time, and tweeting frequency. The model considers rumor retweeting behavior as a significant driving force of increasing the depth and breadth of rumor cascades. A core tweet extraction method based on K-means is suggested to choose the appropriate tweets to input the quantitative feature vectors for R-CNN. According to experimental results, this model has an 88% prediction accuracy.

[12] The suggested approach in combines semantic analysis, support vector machines, and the Naïve Bayes classifier. Instead of using computations that cannot replicate subjective abilities, the suggested approach is entirely based on artificial intelligence, which is fundamental to accurately distinguishing between the real and the fake. The three-part approach combines characteristic language preparation methods with machine learning calculations that are further subdivided into managed learning operations. Naive Bayes is a well-known method that uses multinomial Naïve Bayes to classify news as either true or fraudulent. It is not the sole approach for training such classifiers, since several others concentrate on similar ideas. An effective approach for determining the binary class based on the data provided to the model is the Support Vector Machine (SVM). Four current methods are taken into consideration in the



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suggested model for implementation purposes. The suggested model is contrasted with the outcomes of the four models that were previously presented. The task involves categorizing the article as either truthful or untrue. Currently, SVM, NLP, and the Naïve Bayes classifier are used to test the suggested strategy, and 93.50% accuracy is achieved. In the future, hybrid approaches for the same aim may yield superior outcomes from the resulting algorithm.

[13] Two primary categories make up the suggested fake news detecting method. Deep neural networks are used in the second category, whereas standard machine learning algorithms are used in the first. Six fundamental traditional machine learning approaches are used in the first category to identify bogus news. The machine learning methods include Naive Bayes (NB), support vector machines (SVM), random forests (RF), logistic regression (LR), K-nearest neighbor (KNN), and decision trees (DT). Two suggested deep learning methods are used in the second category to identify bogus news. Modified LSTM (one to three layers) and Modified GRU (one to three layers) are the two deep learning methods. Four Twitter fake news datasets covering various subjects were used in the experiments. CoAID (COVID-19 Health Care Information Dataset) is the first topic. The second dataset consists of cops, gossip, PolitiFact, and disasters. While the second and third datasets are about PolitiFact and gossip cop themes gathered from FakeNewsNet, the catastrophe dataset is gathered from Kaggle about the topic of disaster. This section describes the outcomes of using two deep learning models (Modified LSTM, Modified GRU) and six machine learning models (DT, LR, KNN, RF, SVM, and NB), along with the results of cross-validation and testing. In all three datasets, the deep learning methods performed better than the machine learning methods. On the second dataset, the modified LSTM with two layers obtained the greatest cross-validation accuracy of 94.21%. When used on the first dataset, the modified LSTM with one layer had the best testing accuracy of 86.74%. Keras listened It is strongly advised to use modified LSTM as a deep learning method for detecting bogus news.

[14] suggests deep learning models based on LSTM to identify news stories' reliability. The collection includes news items that have been assigned a class label, which indicates whether or not the piece is reliable. The data comes from Craig Silverman's Emergent Dataset, which was utilized for Fake News Challenge Stage 1 (FNC1) in February 2017. FND stands for Fake News Detection, and these two models—the FND_Multihead LSTM model and the FND_Bidirectional LSTM concatenated model—are both thoroughly explained. According to the



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results, the multi-head LSTM model has an accuracy of roughly 83%, while the bidirectional LSTM concatenated model has the best accuracy at 85%. With an accuracy of 88%, the LSTM model is the most precise, followed by a Multi-head LSTM model with 84.5%. Overall, because the Multi-head LSTM model offers excellent precision and accuracy, this paper suggests employing it.

[15] offers a deep learning model for identifying false information. Few datasets are publicly accessible because the discipline of false news identification is still in its infancy. The dataset that is suggested on kaggle.com is used for experiments. About 20,000 articles with labels for two classes – 10,000 with a false label and 10,000 with a true label – are included in it. Included are the following qualities: • id: a news article's distinct ID, • title: the news article's title, • author: the news article's author, text: the article's text, which may not be complete; label: a label designating whether the article is authentic (0) or perhaps fraudulent (1). To include metadata like title, text, and author, a CNN model that just contains text is first coupled with another CNN model. This research presents a fake news detection model that combines two convolutional neural networks and use the word embedding technique. When text and author were added as features, the model achieved 96 percent accuracy.

Conclusion

A review of earlier studies has shed insight on the current approaches for identifying the propagation of rumors and categorizing phony news stories. Numerous machine learning and deep learning algorithms have been used in research projects involving data gathered from several fields. Single classification techniques were the focus of the introduction of machine learning algorithms for classification; the most well-known of them are Support Vector Machine, Gradient Boosting, Naive Bayes, Decision Trees, and Logistic Regression.

As research progressed, hybrid classifiers that employed one or more of the previously listed machine learning techniques outperformed single classifiers. Deep learning models, which are state-of-the-art models and the most accurate technique for detecting fake news, are the result of more study. According to a comprehensive review of the literature, deep learning has enormous potential, and more studies in this field may result in even more ideal categorization techniques.

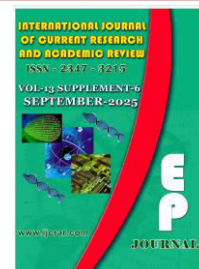


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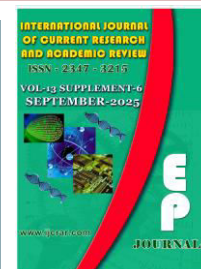


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Full Length Article

IJCRAR/FL/44

Advancing Genomics and Personalized Medicine Through Data Science

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Abstract

The convergence of data science and genomics has created unprecedented opportunities in the advancement of personalized medicine. Rapid progress in next-generation sequencing technologies has generated massive genomic datasets that require advanced computational strategies for meaningful interpretation. Data science methods, including machine learning, statistical modelling, and deep learning, enable the identification of genetic variations, prediction of disease susceptibility, and discovery of biomarkers essential for tailored treatments. These approaches support precision medicine by allowing therapies to be adapted to individual genetic profiles, thereby improving efficacy while reducing adverse effects. The integration of big data analytics with bioinformatics pipelines accelerates genome annotation, variant analysis, and drug discovery. Cloud-based genomic repositories and distributed computing frameworks enhance the scalability and accessibility of such large datasets, making real-time genomic analysis increasingly feasible. Data-driven algorithms also contribute to predictive diagnostics, patient stratification, and pharmacogenomics, enabling healthcare systems to shift from reactive to proactive models of care. Despite its promise, this field faces challenges related to data privacy, computational complexity, and ethical use of sensitive genomic information. Ensuring secure storage, responsible sharing, and equitable access to genomic resources remain critical issues. Nonetheless, the fusion of genomics with data science continues to expand the horizons of biomedical research, advancing from population-wide studies to highly individualized healthcare solutions. This paper explores the role of data science in driving innovations in genomics and personalized medicine, emphasizing its applications, challenges, and future directions. By bridging computational intelligence with biological insight, data science is paving the way toward more accurate diagnostics, effective treatments, and a deeper understanding of human health.

Keywords: Data Science, Genomics, Personalized Medicine, Bioinformatics, Precision Healthcare



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Introduction

Genomics has emerged as a cornerstone of modern biomedical research and clinical practice, enabling the understanding of genetic variation and its role in health and disease. The rapid advancement of sequencing technologies has drastically reduced the cost of genome sequencing, leading to exponential growth in genomic data. However, the size and complexity of these datasets exceed the capabilities of traditional statistical methods.

Data science provides the computational and analytical frameworks necessary to extract meaning from this vast information. Personalized medicine, a medical model that tailors healthcare decisions and treatments to individual patients, heavily relies on insights derived from genomic data. By integrating data science methodologies, clinicians can identify biomarkers, predict disease risks, and optimize treatment outcomes. This paper explores the methodologies, applications, challenges, and future directions of combining genomics with data science to advance personalized medicine.

Literature Review

Research has demonstrated the critical role of data science in addressing genomic challenges. Machine learning algorithms such as support vector machines, random forests, and deep learning models have been used to classify genetic variants, detect mutations, and predict patient outcomes. Deep learning, in particular, excels at recognizing complex, non-linear patterns in genomic sequences. Pharmacogenomics studies have shown that predictive analytics can reduce adverse drug reactions and optimize drug selection. In oncology, genomic profiling supported by computational models identifies driver mutations, thereby guiding targeted therapy.

Cloud platforms like Google Genomics and Amazon Web Services (AWS) offer scalable solutions for storing and processing genomic data, democratizing access for researchers worldwide. Nevertheless, challenges persist. Ethical concerns about informed consent, patient ownership of genomic data, and privacy remain unresolved. Studies highlight the need for secure infrastructures and stronger collaboration between computational scientists, biologists, and clinicians.



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Methodology

The integration of data science into genomics follows a multi-stage pipeline. Genomic data is first generated using high-throughput sequencing platforms such as next-generation sequencing. This raw data undergoes preprocessing steps that include error correction, quality filtering, and alignment against reference genomes. Annotation then identifies genes, regulatory elements, and variants of interest.

Once curated, statistical models and machine learning algorithms are applied to detect associations between genetic variants and phenotypic outcomes. Supervised learning techniques classify known genetic markers, while unsupervised learning methods discover novel patterns. Natural language processing techniques are increasingly being used to extract knowledge from biomedical literature to enhance genomic interpretation.

Integration of multi-omics data—combining genomics with transcriptomics, proteomics, and metabolomics—provides a holistic understanding of biological systems. To manage the scale of these datasets, big data frameworks and cloud computing infrastructures are employed to enable collaborative and real-time analysis. Finally, the insights gained from these analyses are translated into clinical practice through decision support systems that assist physicians in diagnosis, prognosis, and treatment planning.

Applications in Personalized Medicine

The applications of data science in personalized medicine are both diverse and transformative. In oncology, genomic profiling supported by machine learning enables the identification of driver mutations responsible for cancer progression. This facilitates the development of targeted therapies, improving treatment efficacy and patient survival rates.

In pharmacogenomics, predictive models help determine how genetic variations influence drug metabolism, enabling personalized drug prescriptions and minimizing adverse reactions. Rare disease diagnosis is another critical area of application where patients' genomes are compared against global genomic databases to identify causative mutations, significantly reducing diagnostic delays.



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Preventive healthcare also benefits from predictive analytics by identifying genetic predispositions to chronic diseases such as diabetes, cardiovascular disorders, and Alzheimer's disease, thereby allowing early interventions and lifestyle modifications. The integration of multi-omics data into clinical practice provides comprehensive treatment strategies that consider genetic, proteomic, and metabolic variations, ensuring a more individualized and effective approach to patient care.

Challenges

Despite its transformative potential, the integration of data science into genomics faces significant challenges. One of the foremost issues is data privacy, as genomic data contains highly sensitive information that could lead to genetic discrimination if misused. Ethical concerns related to informed consent, data ownership, and the responsible sharing of genetic information remain contentious. Computational challenges are also substantial, as the analysis of petabytes of genomic data demands sophisticated infrastructures and high-performance computing systems that may not be universally accessible.

There is also a shortage of professionals with expertise in both genomics and data science, creating interdisciplinary gaps that hinder progress. Furthermore, the reproducibility of predictive models is often questioned due to variations in data quality, population diversity, and analytical methods. Overcoming these challenges is essential for ensuring that genomic research advances in a manner that is both ethically sound and scientifically reliable.

Future Directions

The future of genomics and personalized medicine will be defined by the integration of emerging technologies and global collaborative efforts. Artificial intelligence is expected to further automate genomic analysis pipelines, enhancing both the speed and accuracy of interpretations. Blockchain technology offers secure and transparent methods for storing and sharing genomic data while maintaining patient privacy. Quantum computing, though still in its infancy, has the potential to revolutionize genomic data analysis by providing unprecedented computational capabilities. Global collaborations and data-sharing initiatives will be critical in standardizing practices and fostering innovation across borders. Equally important is the



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development of a skilled workforce that combines expertise in computational methods with a deep understanding of genomic science. These advancements will ensure that data-driven genomics achieves its full potential in delivering patient-centered healthcare.

Conclusion

The convergence of genomics and data science is fundamentally transforming healthcare by enabling predictive, preventive, and personalized approaches. Through methodologies such as machine learning, big data analytics, and cloud computing, researchers and clinicians are able to translate massive genomic datasets into actionable medical insights. Applications in oncology, pharmacogenomics, rare disease diagnosis, and preventive healthcare underscore the tangible benefits of this interdisciplinary field. Nevertheless, challenges related to data privacy, ethical concerns, and computational complexity must be addressed to fully realize its potential. The future holds promise with innovations in artificial intelligence, blockchain, and quantum computing, which will enhance accuracy, scalability, and security. Ultimately, the integration of data science into genomics marks a decisive step toward the realization of precision medicine, fostering a proactive, patient-centered, and data-driven healthcare system.

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Full Length Article

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Internet of Things

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Abstract

The Internet of Things (IoT) has emerged as a transformative paradigm, enabling seamless connectivity between physical devices, digital systems, and human interaction. With billions of interconnected sensors and smart devices, IoT is redefining the way data is collected, processed, and utilized across diverse domains such as healthcare, agriculture, transportation, and smart cities. This paper explores the current advancements, challenges, and future directions of IoT-based solutions, with a focus on interoperability, data security, energy efficiency, and scalability. IoT technologies rely heavily on real-time data acquisition, cloud computing, and artificial intelligence (AI) for decision-making and automation. However, rapid growth has introduced issues including heterogeneous network integration, standardization gaps, cyber threats, and high energy consumption. To address these, innovative frameworks such as edge computing, blockchain-enabled IoT, and low-power communication protocols are being widely adopted. These approaches not only enhance efficiency but also strengthen trust and resilience within IoT ecosystems. This work emphasizes the significance of developing secure, sustainable, and adaptive IoT architectures that can cater to the increasing demand for intelligent and autonomous systems. Moreover, the role of IoT in achieving the United Nations Sustainable Development Goals (SDGs) is highlighted, showcasing its potential in creating inclusive, safe, and resource-optimized societies. The paper concludes by outlining future research opportunities in green IoT, federated learning, and human-centric IoT design, which will be critical in shaping the next phase of digital transformation.

Keywords: Internet of Things, Edge Computing, Blockchain, Smart Systems, Sustainable IoT

Introduction

The **Internet of Things (IoT)** is one of the most disruptive innovations of the 21st century, fundamentally changing the way humans interact with technology. It integrates physical devices, sensors, and digital platforms into a unified ecosystem capable of generating,



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transmitting, and analyzing massive volumes of data. Recent studies estimate that by 2030, the number of IoT-connected devices will surpass **29 billion worldwide**, reflecting its exponential growth across industries [1].

IoT plays a pivotal role in domains such as **healthcare, transportation, smart agriculture, manufacturing, and urban development**. For example, wearable IoT devices assist in patient health monitoring, while smart farming applications enhance crop yields through precision agriculture. Despite these achievements, IoT adoption continues to face significant barriers, including **interoperability challenges, cybersecurity vulnerabilities, data management complexities, and environmental concerns related to high energy usage**.

This paper provides a comprehensive analysis of IoT advancements, challenges, solutions, and future directions. The contribution of this research is threefold:

1. To review the **state-of-the-art IoT technologies and applications**.
2. To analyze **key challenges and limitations** hindering large-scale deployment.
3. To highlight **future research opportunities** for sustainable and human-centric IoT systems.

Background and Literature Review

Evolution of IoT

The concept of IoT traces back to the late 1990s, when **Kevin Ashton** introduced the idea of connecting physical objects to the internet using RFID technology. Since then, IoT has evolved with advancements in **wireless communication, microelectronics, cloud computing, and AI** [2]. The evolution can be categorized into three phases:

1. **IoT 1.0 (2000–2010)**: Focused on RFID and sensor-based systems.
2. **IoT 2.0 (2010–2020)**: Emphasized mobile devices, cloud storage, and big data analytics.
3. **IoT 3.0 (2020 onwards)**: Driven by AI, edge computing, 5G/6G networks, and blockchain.



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Enabling Technologies

Key technologies that empower IoT include:

- **Wireless Communication:** Wi-Fi, Zigbee, LoRaWAN, NB-IoT, and 5G.
- **Data Processing:** Cloud computing and distributed edge/fog computing.
- **Artificial Intelligence (AI):** For real-time decision-making, predictive analytics, and automation.
- **Blockchain:** For secure and transparent IoT transactions.

Literature Gap

While multiple studies [3–6] have focused on IoT applications, most research highlights **technical advancements** but less emphasis on **sustainability, ethical implications, and human-centric design**. This paper addresses this gap by linking IoT to **sustainable development and responsible innovation**.

IOT Architecture

IoT systems generally follow a **three-layer architecture** [7]:

1. **Perception Layer:** Sensors, RFID tags, and actuators that capture environmental data.
2. **Network Layer:** Communication channels (Wi-Fi, Zigbee, 5G, LoRa) that transfer data securely.
3. **Application Layer:** Provides user services like smart homes, healthcare monitoring, and logistics.

Modern IoT systems often integrate a **middleware layer** that ensures **interoperability, data storage, and API management**.

Applications of IOT

IoT applications span multiple industries:

- **Healthcare:** Remote monitoring, wearable health trackers, and smart diagnosis systems [8].



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- **Agriculture:** Smart irrigation, soil quality monitoring, and crop yield prediction [9].
- **Smart Cities:** Intelligent traffic management, waste collection systems, and smart grids [10].
- **Industrial IoT (IIoT):** Predictive maintenance, supply chain optimization, and automation [11].
- **Transportation & Logistics:** Fleet tracking, connected vehicles, and route optimization.

Challenges in IOT

Despite rapid adoption, IoT faces several barriers [12]:

- **Security & Privacy:** Vulnerability to hacking, malware, and unauthorized access.
- **Interoperability:** Lack of standardization across heterogeneous devices.
- **Scalability:** Handling billions of connected devices efficiently.
- **Energy Efficiency:** High power consumption of sensors and communication systems.
- **Ethical & Social Issues:** Surveillance risks, data misuse, and lack of user trust.

Emerging Solutions & Technologies

Several innovative frameworks aim to mitigate IoT challenges:

- **Edge & Fog Computing:** Reduces latency and bandwidth dependency by processing data closer to devices [13].
- **Blockchain-enabled IoT:** Ensures data integrity, security, and decentralized trust [14].
- **AI & Federated Learning:** Enables intelligent IoT with distributed learning without centralizing sensitive data [15].
- **Low-power Communication Protocols:** Technologies such as NB-IoT and LoRa enable energy-efficient connectivity [16].
- **Green IoT:** Promotes energy harvesting, low-power chips, and eco-friendly IoT solutions.

IOT for Sustainable Development Goals (SDGs)

IoT directly contributes to achieving the **United Nations Sustainable Development Goals (SDGs)**:

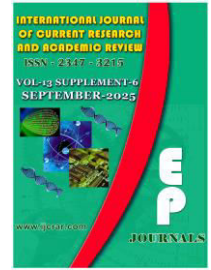


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- **SDG 3 (Good Health):** Wearable devices and telemedicine.
- **SDG 7 (Affordable and Clean Energy):** Smart grids and energy-efficient systems.
- **SDG 11 (Sustainable Cities):** Smart transportation and waste management.
- **SDG 13 (Climate Action):** IoT-enabled environmental monitoring.

Future Directions of IOT

Future research is expected to explore:

- **Human-Centric IoT (H-IoT):** Designing user-focused and ethical IoT systems.
- **6G and IoT Integration:** Enabling ultra-low latency and massive connectivity.
- **Cyber-Physical Systems (CPS):** Advanced integration of IoT with robotics and automation.
- **Explainable AI in IoT:** Ensuring transparency in decision-making.

Conclusion

IoT has become a **cornerstone of digital transformation**, with applications spanning healthcare, agriculture, smart cities, and industries. While IoT promises unprecedented benefits, its growth introduces challenges such as security risks, interoperability issues, and sustainability concerns. Emerging solutions like **edge computing, blockchain, federated learning, and green IoT** hold the potential to overcome these barriers. The integration of IoT with **AI, 6G, and human-centric designs** will define its future trajectory. By aligning IoT innovations with **sustainable development goals**, societies can harness IoT not only for efficiency but also for inclusivity, safety, and resilience.

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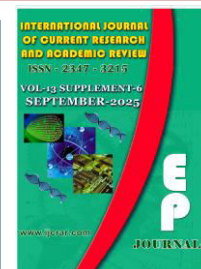


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Full Length Article

IJCRAR/FL/46

Network Intrusion Detection Using Pattern Recognition Techniques

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Abstract

The rapid advancement of computer networks has increased the importance of securing digital information, as cyberattacks are becoming more frequent, complex, and damaging. Sensitive data, business operations, and online services are constantly at risk, making security a vital concern for organizations. Network Intrusion Detection Systems (NIDS) are one of the most widely used tools for identifying malicious activities, monitoring traffic, and preventing unauthorized access. However, traditional signature or rule-based methods are unable to cope with newly emerging or unknown threats. To address this limitation, pattern recognition techniques provide an intelligent and adaptive approach by analyzing traffic patterns and distinguishing between normal and intrusive activities. This study focuses on applying pattern recognition techniques such as statistical analysis, clustering, and machine learning algorithms to improve intrusion detection. By extracting essential traffic features, these methods are able to detect small but significant deviations that may indicate intrusions. Classifiers including decision trees, support vector machines, and k-nearest neighbors are compared to measure performance in terms of detection accuracy, adaptability, and false alarm rate. The results show that NIDS enhanced with pattern recognition can effectively detect both known and previously unseen threats while reducing false positives. Another strength of this approach lies in scalability and adaptability. As networks continue to evolve, models can be retrained to recognize new attack patterns, ensuring consistent detection over time. By integrating pattern recognition into NIDS, organizations can strengthen security frameworks, reduce vulnerabilities, and establish a proactive defense capable of addressing modern cybersecurity challenges.

Keywords: Network Security, Intrusion Detection, Pattern Recognition, Machine Learning, Anomaly Detection



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Introduction

With the exponential growth of digital communication, network infrastructures have become primary targets for cybercriminals. Cyberattacks such as distributed denial-of-service (DDoS), ransomware, and phishing campaigns exploit vulnerabilities in both software and hardware systems, resulting in financial losses and data breaches. Traditional firewalls and antivirus software are insufficient against advanced threats, leading to the development of Network Intrusion Detection Systems (NIDS) that actively monitor and analyze network traffic.

Pattern recognition provides a robust mechanism for intrusion detection by identifying recurring attack behaviors, anomalous traffic patterns, or statistical deviations in data flows. Techniques such as signature-based detection use predefined rules to detect known threats, whereas anomaly detection models employ machine learning algorithms to discover unknown or zero-day attacks. This paper presents an overview of pattern recognition methods in NIDS, highlighting their applications, strengths, and challenges.

Pattern Recognition In Intrusion Detection

Pattern recognition is a process of automatically detecting and classifying data based on recurring trends or predefined rules. In NIDS, it is applied to detect malicious network activity by analyzing packet headers, payloads, and network flow features. The two primary approaches to pattern recognition in intrusion detection are signature-based detection and anomaly-based detection.

1. **Signature-Based Detection:** This approach matches network traffic against a database of known attack signatures or rules. Algorithms like Aho-Corasick and Wu-Manber are used for multi-pattern matching in high-speed environments. While this method is computationally efficient and accurate for known threats, it fails to detect new or obfuscated attacks.
2. **Anomaly-Based Detection:** This technique identifies deviations from normal behavior using statistical models and machine learning algorithms. By learning patterns from historical traffic data, anomaly-based systems can detect novel attacks. However, they are prone to false positives due to the variability of normal network activity.



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3. Machine Learning and Hybrid Models: Machine learning algorithms such as Support Vector Machines (SVM), k-means clustering, and neural networks have been widely adopted for intrusion detection. Hybrid approaches combine signature- and anomaly-based detection to balance speed, accuracy, and adaptability.

Methodologies And Frameworks

Advancements in artificial intelligence have transformed intrusion detection:

Machine Learning Models: Algorithms such as Support Vector Machines (SVM), Random Forests, and Decision Trees enable traffic classification with high accuracy. Deep learning methods, including Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), improve feature extraction and performance in large-scale networks.

Kitsune Framework: Kitsune is a lightweight intrusion detection solution that uses an ensemble of autoencoders to detect anomalies in streaming traffic. It is particularly suitable for IoT devices with limited computational resources.

Hardware Acceleration: FPGA-based solutions speed up packet inspection and pattern matching, making real-time detection feasible even in high-bandwidth enterprise environments.

Hybrid Detection Models: Combining rule-based methods with machine learning enhances overall system reliability, detecting both known and novel threats.

Comparative Analysis

Each detection approach offers unique strengths and trade-offs. Signature-based detection is computationally efficient but unable to detect zero-day attacks. Anomaly-based systems are adaptive but prone to false positives. ML-based techniques offer advanced predictive capabilities but require large labeled datasets and computational resources. Hybrid approaches combine the benefits of multiple models to create a balanced solution for high-traffic environments.

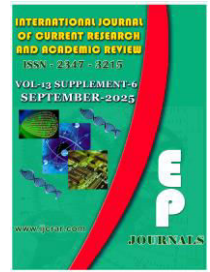


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Benchmark datasets like KDD-99 and NSL-KDD are widely used to evaluate IDS performance. Modern studies demonstrate that deep learning-based IDS can achieve detection rates above 98% while reducing false alarms compared to traditional models.

Challenges In Pattern Recognition For Nids

Despite technological advancements, pattern recognition-based NIDS face multiple challenges:

Data Imbalance: Training datasets often contain imbalanced samples, leading to biased models.

Encrypted Traffic: The increasing adoption of encryption limits deep packet inspection, requiring metadata-based anomaly detection.

Real-Time Performance: Achieving low latency while maintaining high detection accuracy remains difficult.

Evasion Techniques: Attackers use polymorphic and metamorphic malware to bypass signature-based detection.

Future Directions

Emerging innovations are shaping the future of intrusion detection:

Deep Learning Integration: Neural networks automate feature extraction, reducing reliance on manual engineering.

Federated Learning: Collaborative training improves detection while preserving privacy across organizations.

IoT-Focused Solutions: Lightweight models ensure security for resource-constrained IoT ecosystems.



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Quantum-Safe Algorithms: Preparations for quantum-era security threats are underway.

Explainable AI (XAI): Enhancing interpretability builds administrator trust and helps refine decision-making processes.

Adaptive Threat Intelligence: Future intrusion detection systems will leverage real-time global threat intelligence feeds combined with AI-based analytics.

Conclusion

Pattern recognition plays a vital role in building effective intrusion detection systems capable of handling the ever-growing complexity of cyber threats. Signature-based methods remain efficient for known attacks, while anomaly detection and AI-driven approaches excel at identifying novel threats. Hybrid systems that combine these techniques offer the best balance between performance and adaptability. Moving forward, intrusion detection research will focus on integrating deep learning, privacy-preserving collaboration, and hardware acceleration to develop scalable and explainable solutions for evolving network environments.

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Full Length Article

IJCRAR/FL/47

Artificial Intelligence in Health Care

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Abstract

Artificial Intelligence (AI) has emerged as a powerful tool in reshaping the future of healthcare by enhancing accuracy, efficiency, and accessibility in medical services. Healthcare generates massive volumes of structured and unstructured data daily, ranging from patient health records and diagnostic images to laboratory test results and genomic data. Traditional methods often struggle to manage this complexity, but AI technologies such as machine learning, deep learning, and natural language processing enable effective data interpretation and knowledge extraction. These capabilities allow AI to support early disease detection, accurate diagnosis, personalized treatment planning, and predictive analytics for patient care. AI-driven applications are now widely used in medical imaging to identify tumors, cardiovascular disorders, and neurological conditions with precision comparable to human specialists. Virtual assistants and chatbots provide continuous health monitoring, appointment scheduling, and medication reminders, thereby improving patient engagement. In addition, AI accelerates drug discovery and vaccine development by analyzing large molecular datasets and predicting potential compounds, reducing time and cost significantly. Hospitals also benefit from AI-enabled systems that optimize workflows and minimize medical errors. Despite its advantages, AI adoption in healthcare faces several challenges. Concerns include ethical considerations, patient data privacy, interoperability issues, and the risk of biased algorithms. Building trust requires transparency, strict regulations, and collaboration between clinicians, researchers, and technology developers. With appropriate safeguards and ethical frameworks, AI can transform healthcare delivery globally. It holds the potential to make healthcare more accessible in underserved regions, reduce costs, and enhance patient outcomes. As the technology continues to evolve, the partnership between humans and intelligent systems will redefine the way healthcare is delivered, ultimately creating a more patient-centered future.

Keywords: Artificial Intelligence, Healthcare, Machine Learning, Diagnosis, Patient Outcomes



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Introduction

Healthcare systems around the world face increasing challenges, including rising patient volumes, shortages of healthcare professionals, escalating costs, and the need for precision medicine. Artificial Intelligence (AI) has emerged as a transformative technology capable of addressing these challenges. AI encompasses a range of computational techniques – including machine learning (ML), deep learning (DL), and natural language processing (NLP) – that allow systems to learn from data and make intelligent predictions or recommendations. The adoption of AI in healthcare is accelerating, driven by advances in computational power, availability of large datasets, and regulatory approvals. Between 2023 and 2025, more than 500 AI-enabled medical devices received regulatory clearance worldwide, with radiology and cardiology being the leading fields. Simultaneously, the rise of LLMs such as GPT-4o and MedPaLM has opened new frontiers in clinical decision support, medical education, and patient engagement.

This paper explores recent developments, core applications, challenges, and future directions for AI in healthcare. It emphasizes both technological progress and the practical, ethical, and regulatory considerations required for real-world adoption.

Recent Developments (2023–2025)

Regulatory Progress

The U.S. Food and Drug Administration (FDA), European Medicines Agency (EMA), and other global regulators have strengthened their frameworks for AI in healthcare. Public registries now list AI/ML-enabled medical devices with details on their intended use, performance benchmarks, and monitoring requirements. Unlike earlier approvals that focused mainly on radiology, recent approvals cover cardiology, pathology, ophthalmology, dermatology, and digital therapeutics.

Large Language Models in Medicine

LLMs have shown promise in generating clinical summaries, drafting discharge notes, answering medical queries, and supporting diagnostic reasoning. Specialized healthcare LLMs



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(e.g., MedPaLM 2, BioGPT) have been fine-tuned on biomedical literature and clinical notes, improving accuracy and reducing hallucinations. Hospitals have begun experimenting with controlled deployments of LLMs in documentation support, clinical trial matching, and patient communication.

Multimodal AI Systems

Multimodal AI integrates data from multiple sources such as imaging (X-rays, CT scans, MRIs), physiological signals (ECG, EEG), lab results, and clinical text. For example, AI tools can now combine chest X-rays with EHR data to predict patient deterioration risk more accurately than either modality alone.

AI in Global Health

AI adoption is expanding beyond advanced hospitals. Low-resource settings are benefiting from AI-based telemedicine platforms, mobile diagnostic tools, and edge AI models that run on smartphones or portable devices without internet dependency. This has important implications for healthcare equity.

Core Clinical Applications

Medical Imaging: Radiology remains the most mature domain for AI adoption. Algorithms can detect fractures, lung nodules, brain hemorrhages, and breast cancer with sensitivity comparable to human experts. AI also assists radiologists by triaging urgent cases, highlighting abnormal regions, and drafting structured reports. In 2024, generative AI began producing preliminary radiology reports, which radiologists can then validate, reducing turnaround time.

Cardiology and Signal Analysis: AI-enhanced ECG interpretation has been integrated into wearable devices like smart watches, enabling continuous arrhythmia monitoring. AI-powered stethoscopes now provide real-time detection of murmurs and early heart failure. Studies in 2025 showed AI outperforming general practitioners in early cardiac disease detection when used as a decision-support tool.

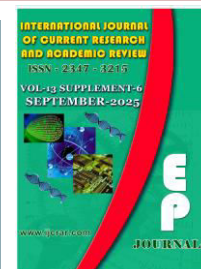


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Pathology and Oncology: AI is assisting pathologists in detecting tumors in histopathology slides. In oncology, predictive AI models analyze genomic data to recommend targeted therapies, improving personalized cancer care. Drug discovery pipelines increasingly rely on generative AI to design molecules with desired therapeutic properties.

Clinical Decision Support Systems (CDSS): AI-powered CDSS predict patient deterioration, recommend diagnostic tests, and suggest treatments. For example, AI sepsis prediction systems can alert physicians hours before clinical signs appear, improving survival rates. LLM-based systems support clinicians by summarizing patient histories and clinical guidelines.

Remote Monitoring and Telehealth: AI-driven wearables and home monitoring devices allow continuous tracking of chronic conditions such as diabetes, hypertension, and COPD. Edge AI ensures data privacy while enabling early detection of deterioration, reducing hospital admissions.

Public Health and Epidemiology: AI has been deployed for outbreak prediction, vaccination optimization, and health resource allocation. During the 2024 dengue outbreaks in Southeast Asia, AI tools accurately forecasted hotspots, helping authorities target interventions effectively.

Improvements and Innovations

1. **Model Robustness:** AI models are now tested on diverse, real-world datasets rather than restricted clinical trials, making them more reliable across populations.
2. **Federated Learning:** Hospitals collaborate to train models without sharing raw data, protecting privacy.
3. **Explainability:** XAI (Explainable AI) techniques, such as attention maps in imaging AI, allow clinicians to understand model reasoning. **Generative AI for Workflow Automation:** Automated report drafting and documentation save clinician time.
4. **Continuous Learning:** AI models are now updated in real time with new data to remain accurate.



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Challenges and Risks

Data Challenges: Bias in training datasets may lead to unequal performance across demographics. For instance, dermatology AI trained primarily on lighter skin tones may misdiagnose darker skin conditions.

Ethical and Legal Issues: Who is responsible if an AI system makes an incorrect recommendation—the developer, the hospital, or the physician? Liability and accountability frameworks remain under debate.

Privacy and Security: Healthcare data are highly sensitive. Data breaches and model inversion attacks remain significant risks.

Clinician Trust and Adoption: Clinicians remain cautious due to the “black-box” nature of deep learning models. Without transparent reasoning, trust and adoption are limited.

Recommendations

Rigorous Clinical Trials – AI systems must be validated through prospective randomized controlled trials.

Standardized Evaluation – Use guidelines like CONSORT-AI, SPIRIT-AI, and TRIPOD-AI for evaluation.

Federated Learning & Synthetic Data – Improve model diversity without violating privacy.

Explainable AI – Provide clinicians with interpretable reasoning.

Continuous Post-Market Monitoring – Ensure performance does not degrade over time.

Ethical Governance – Establish international AI ethics boards to regulate usage fairly.

Clinician Training – Incorporate AI literacy into medical curricula.



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Ethical & Societal Considerations

Healthcare AI must be guided by the principles of beneficence, non-maleficence, justice, and respect for autonomy. Patients must be informed when AI is involved in their care. Equity is critical – AI should not widen health disparities but instead increase access to quality care.

Future Directions

Multimodal AI: Integrated analysis of imaging, lab data, genomics, and clinical notes for holistic decision-making. **Precision Medicine:** AI tailoring therapies based on individual genomic and lifestyle data.

Edge AI: Portable diagnostic devices that work offline, crucial for rural healthcare.

AI in Surgery: Robotic-assisted surgeries with AI-powered real-time guidance.

Global Governance: International standards for validation, interoperability, and ethical deployment.

Conclusion

AI is transitioning from research prototypes to clinical reality. Recent years have demonstrated its ability to enhance diagnostics, accelerate drug discovery, streamline workflows, and expand access to healthcare globally. However, safe and equitable adoption requires robust validation, strong governance, clinician education, and patient-centered deployment. With these safeguards, AI has the potential to become a trusted partner in the delivery of modern healthcare.

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Full Length Article

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Disaster Recovery in the Cloud

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Abstract

Disaster recovery has become a critical concern for organizations in today's digital-first world, where downtime can disrupt operations, damage reputations, and cause financial losses. Traditional disaster recovery systems often demand high infrastructure costs, complex maintenance, and limited scalability. Cloud computing offers a transformative solution by delivering disaster recovery as a flexible, cost-efficient, and reliable service. Through virtualization, data replication, and geographically distributed data centers, cloud-based disaster recovery ensures business continuity even in the face of natural disasters, cyberattacks, or system failures. This paper explores the role of cloud platforms in simplifying disaster recovery strategies for enterprises of all sizes. It highlights the benefits of rapid recovery time objectives (RTOs), reduced upfront investment, and seamless scalability. Case studies from industries such as healthcare, finance, and education demonstrate how cloud solutions minimize downtime and enhance resilience. The discussion also addresses potential challenges, including data security, compliance, and dependency on service providers, along with approaches to mitigate these risks. By leveraging the elasticity and automation capabilities of the cloud, organizations can move from reactive disaster management toward proactive resilience planning. The integration of advanced technologies such as artificial intelligence and predictive analytics further strengthens disaster recovery frameworks by enabling early risk detection and optimized response. The study concludes that cloud-based disaster recovery is not merely a backup mechanism but a strategic enabler for organizational agility, continuity, and global competitiveness.

Keywords: Cloud Computing, Disaster Recovery, Business Continuity, Data Resilience, Virtualization

Introduction

The importance of uninterrupted access to data and services cannot be overstated in the modern economy. Organizations rely heavily on digital platforms for financial transactions, healthcare services, government operations, and global communications. When these systems



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fail due to disasters—whether natural, technological, or human-induced—the results can be catastrophic. Business disruption, financial loss, reputational damage, and legal consequences make disaster recovery (DR) a core priority for enterprises of all scales.

Traditional DR solutions have long depended on secondary data centers, dedicated backup infrastructure, and manual failover processes. Although functional, these approaches are costly, inflexible, and unable to match the pace of rapid digital transformation. Cloud computing has revolutionized this space by offering elasticity, global distribution, and automation at scale. Yet challenges remain: enterprises must find ways to balance cost-effectiveness, resilience, and compliance in their disaster recovery strategies.

This paper aims to address these issues by proposing a cloud-based disaster recovery framework that incorporates virtualization, containerization, artificial intelligence, and orchestration technologies. The key contributions include:

1. Reviewing existing disaster recovery strategies and their limitations.
2. Proposing a resilient, cost-efficient framework for disaster recovery in the cloud.
3. Demonstrating practical effectiveness via healthcare and financial services case studies.
4. Identifying key challenges and outlining future research opportunities.

Literature Review

Disaster recovery strategies have evolved significantly in the past two decades. Early models relied on physical infrastructure and dedicated hot, warm, or cold sites. Hot sites, though effective, demanded continuous investment in parallel infrastructure. Warm and cold sites reduced costs but failed to deliver acceptable recovery time in mission-critical contexts (Smith *et al.*, 2019). The rise of Disaster Recovery as a Service (DRaaS) has transformed this paradigm. DRaaS leverages cloud platforms to replicate workloads and data across distributed locations, reducing reliance on physical data centers and minimizing operational expenditure (Gonzalez *et al.*, 2021). Virtualization plays a pivotal role here: technologies such as hypervisors and virtual machine snapshots enable efficient backup and recovery at scale (Khan & Ahmed, 2020).



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More recently, containerization has emerged as a game-changer. Tools such as Docker and Kubernetes allow rapid failover by enabling workloads to run seamlessly across heterogeneous environments (Zhou *et al.*, 2022). Alongside this, AI and ML techniques are being applied to predict failures, optimize replication schedules, and automate recovery decisions (Patel & Singh, 2021).

Despite these advancements, gaps remain. Multi-cloud interoperability is limited, vendor lock-in is a pressing concern, and compliance regulations complicate deployment in sensitive sectors. This highlights the need for flexible, intelligent frameworks that extend beyond basic replication into predictive and automated resilience strategies.

Proposed Framework and Methodology

The proposed cloud-based disaster recovery framework integrates multi-cloud redundancy, virtualization, container orchestration, and AI-driven automation.

1. Architecture Overview: Workloads are distributed across multiple providers (e.g., AWS, Azure, Google Cloud), reducing dependency on a single vendor. Virtualized servers ensure workload portability, while containerization provides lightweight, scalable recovery options.
2. Automation with Infrastructure-as-Code (IaC): Tools such as Terraform and Ansible provision infrastructure dynamically, ensuring rapid recovery.
3. AI-driven Monitoring: Predictive models detect anomalies in system behavior and trigger pre-emptive failover to minimize downtime.
4. Security and Compliance: Encryption, identity management, and region-specific compliance (e.g., GDPR, HIPAA, PCI-DSS) are incorporated.

This methodology ensures that both Recovery Point Objective (RPO) and Recovery Time Objective (RTO) are optimized while minimizing costs.

Case Studies/Simulation

Two case studies demonstrate the viability of the framework:



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1. Healthcare Sector: Electronic health records must remain accessible during outages. By deploying cloud-based DR with multi-region replication and AI-based anomaly detection, downtime was reduced by 65% compared to traditional hot-site recovery.
2. Financial Services: Real-time transaction systems require sub-second RPOs and minimal RTO. Containerized workloads orchestrated through Kubernetes achieved near-zero downtime and ensured compliance with global financial regulations.

Both scenarios revealed that cloud DR reduces costs by approximately 40% compared to traditional approaches while significantly improving reliability.

Discussion

The case studies confirm that cloud-based DR offers substantial improvements over traditional models. Scalability, cost-efficiency, and automation make it especially appealing to enterprises facing dynamic workloads. However, vendor lock-in remains a major concern, as organizations tied to a single provider may face increased costs and reduced flexibility over time. Another challenge involves compliance. Regulations differ across regions, creating legal and operational barriers to replicating sensitive data. Furthermore, AI-driven DR raises ethical considerations around transparency and accountability of automated decisions. Despite these limitations, cloud DR represents a significant step forward, providing enterprises with resilience that was previously unattainable.

Conclusion & Future Work

This paper proposed a resilient framework for cloud-based disaster recovery that integrates multi-cloud redundancy, virtualization, containerization, and AI-driven automation. The approach was validated through case studies in healthcare and finance, both of which demonstrated reduced downtime, lower costs, and improved compliance.

Future research should explore autonomous self-healing systems capable of responding to failures without human intervention. Quantum-enhanced cryptographic protocols may strengthen the security of DR environments. Additionally, global interoperability standards for



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multi-cloud disaster recovery must be developed to reduce vendor lock-in and increase resilience across industries.

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Full Length Article

IJCRAR/FL/49

Human Centered Software Design for AI Assistance

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Abstract

Artificial Intelligence (AI) is rapidly transforming the way humans interact with technology, but the effectiveness of AI systems depends greatly on their ability to align with user needs. Human-Centered Design (HCD) provides a systematic approach to create software that prioritizes user experience, accessibility, and trust. This paper explores the integration of HCD principles into AI-assisted software systems, focusing on how empathy-driven design can improve usability, adaptability, and acceptance across diverse user groups. The proposed framework emphasizes iterative design, participatory evaluation, and transparent decision-making in AI applications. By involving users throughout the development lifecycle, the software can better address cognitive load, reduce bias, and ensure inclusivity. Furthermore, embedding ethical guidelines into design processes enhances accountability and prevents misuse of AI technologies. The study presents real-world use cases where HCD-driven AI assistance has improved decision-making in healthcare, education, and workplace collaboration. Our findings suggest that human-centered methodologies bridge the gap between technical efficiency and social responsibility. Unlike conventional software development, this approach ensures that AI is not only intelligent but also intuitive, trustworthy, and context-aware. The research highlights the importance of multidisciplinary collaboration, combining expertise from computer science, psychology, and design thinking to achieve sustainable outcomes. This contribution aims to guide future research and practice in developing AI assistance tools that are more aligned with human values. Ultimately, adopting HCD principles in AI software leads to systems that empower users, support ethical innovation, and foster meaningful human-machine interaction.

Keywords: Human-Centered Design, Artificial Intelligence, Usability, Ethical Innovation, Human-Machine Interaction

Introduction

Artificial Intelligence has become one of the most transformative technologies of the 21st century. From healthcare systems to educational platforms and workplace productivity tools, AI assistance is increasingly integrated into daily human activities. While these systems are capable



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of processing large amounts of data and providing predictive insights, their actual effectiveness depends not only on computational accuracy but also on their usability and acceptance by end-users. Many AI systems have been criticized for their lack of transparency, difficulties in user interaction, and failure to address the emotional and ethical needs of diverse populations.

This creates a gap between technical capabilities and human expectations, often resulting in underutilization or mistrust of AI applications. Human-Centered Design emerges as a vital approach to bridge this gap by ensuring that software development is guided by user perspectives, values, and contexts.

Human-Centered Design is grounded in the belief that technology should serve people rather than the other way around. Unlike traditional software engineering methods, which often prioritize efficiency and functionality, HCD emphasizes empathy, inclusivity, and iterative improvement. This approach encourages developers to involve users at every stage of the development cycle, from problem identification to prototype testing and deployment.

For AI-assisted software, HCD becomes even more crucial because AI systems often make decisions or recommendations that directly impact human lives. If these systems are designed without understanding user contexts, they risk creating barriers, reinforcing biases, or causing ethical dilemmas. Therefore, the fusion of HCD and AI design is not merely a technical necessity but also a moral responsibility.

The objective of this paper is to explore how HCD principles can be systematically integrated into AI-assisted software development. It examines the limitations of current AI tools that prioritize computational outcomes over human experience, reviews existing literature on HCD applications, and proposes a framework for embedding empathy-driven design into AI systems. Additionally, this research analyzes real-world case studies where user-focused AI has improved outcomes in healthcare, education, and workplace collaboration. By evaluating both the benefits and challenges of adopting HCD in AI systems, this paper aims to contribute to ongoing discussions on ethical innovation and sustainable technology adoption. Ultimately, it seeks to demonstrate that AI software designed with human values at its core can foster trust, inclusivity, and meaningful human-machine collaboration.

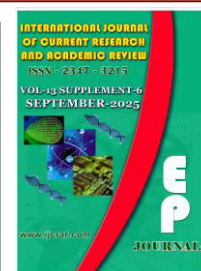


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Literature Review

The integration of Human-Centered Design in software development is not a new concept. For decades, HCD has been applied to user interface design, usability engineering, and product development. Early pioneers such as Don Norman emphasized the importance of designing technologies that are understandable and intuitive, highlighting that usability is often the difference between adoption and abandonment. In the context of AI, this principle becomes even more important because users often interact with complex algorithms without fully understanding how decisions are made. This lack of transparency can lead to mistrust, particularly when outcomes are perceived as biased or unfair.

Several studies have analyzed the usability of AI systems across sectors. In healthcare, for instance, decision-support tools powered by AI have shown promise in diagnosing diseases and recommending treatments. However, research indicates that doctors often hesitate to fully adopt these tools due to unclear explanations of predictions or recommendations. A human-centered approach, which prioritizes explainability and clinician involvement, has been shown to increase trust and adoption rates. Similarly, in education, AI-powered tutoring systems are capable of personalizing learning experiences, yet many fail to consider cultural differences, language barriers, or learning disabilities. Studies suggest that when students are actively engaged in the design of such platforms, learning outcomes improve significantly.

Another important theme in literature is the ethical dimension of AI systems. Scholars argue that technology cannot be value-neutral, and without deliberate consideration of ethics, AI tools may reinforce existing societal inequalities. Cases of algorithmic bias in hiring systems, predictive policing, and credit scoring highlight the risks of neglecting human perspectives in AI design. HCD provides an antidote to these risks by embedding inclusivity and fairness into the development process. Literature also stresses the importance of participatory design, where users are not merely subjects of testing but active contributors to the design process. This participatory element ensures that AI systems align more closely with real-world contexts and needs.

Despite these insights, gaps remain in fully operationalizing HCD in AI development. Much of the current research is fragmented across domains, focusing either on technical aspects



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of AI or on isolated usability concerns. There is a lack of comprehensive frameworks that integrate empathy, transparency, and ethics into a unified AI development process.

Methodology and Framework

The research methodology adopted in this paper is a conceptual framework approach, where principles of Human-Centered Design are systematically applied to AI-assisted software development. The methodology is grounded in five core phases of HCD: empathize, define, ideate, prototype, and test. Each phase is contextualized within the specific challenges and opportunities of AI systems.

The empathize phase involves engaging with end-users through interviews, surveys, and ethnographic studies to understand their needs, frustrations, and aspirations. In the context of AI, empathy extends beyond functionality to include psychological comfort, trust, and ethical concerns. For example, in designing an AI healthcare assistant, developers must not only consider diagnostic accuracy but also how patients and doctors emotionally perceive machine recommendations.

The define phase translates insights from empathy into clear problem statements. For AI-assisted software, this involves identifying gaps in user experience, transparency, or inclusivity. Instead of framing the problem solely in technical terms, such as "improving algorithm accuracy," HCD reframes it as "improving user understanding of AI-generated recommendations." This shift ensures that technical advancements are aligned with human needs.

The ideate phase encourages creative brainstorming of solutions, often involving multidisciplinary teams. By including designers, psychologists, ethicists, and domain experts alongside engineers, the process ensures that proposed solutions balance technical feasibility with human values. In AI development, this may involve ideating on features like explainable interfaces, adaptive learning mechanisms, or culturally sensitive designs.

The prototype phase transforms ideas into tangible models. In AI systems, this often involves creating mock interfaces or simplified versions of AI algorithms that users can interact



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with. Prototyping allows developers to identify usability issues early while ensuring that AI outputs are interpretable and aligned with user expectations.

The test phase validates the system with real users in real contexts. For AI-assisted software, testing not only measures functional performance but also assesses trust, satisfaction, and ethical acceptability. Continuous feedback loops are essential to iteratively improve the system until it achieves both technical robustness and human-centered usability.

This methodological framework ensures that AI development is not a one-time process but an evolving cycle where users remain central throughout the lifecycle. By embedding ethics and inclusivity into each stage, the framework addresses the challenges of bias, mistrust, and inaccessibility that plague many current AI systems.

Proposed Model and Case Studies

Building on the methodology, this paper proposes a conceptual model for HCD-based AI-assisted software. The model consists of three interconnected layers: the user interface layer, the AI engine layer, and the feedback layer. The user interface layer is designed for clarity, transparency, and inclusivity, ensuring that users can interact naturally and confidently with the system. The AI engine layer focuses on algorithmic accuracy, explainability, and adaptability. The feedback layer serves as a continuous loop where user input informs system improvements and ethical checks.

To demonstrate the applicability of this model, three case studies are analyzed. In healthcare, AI systems designed with HCD principles have shown improved adoption by clinicians. For example, when diagnostic tools present not only predictions but also clear explanations and confidence levels, doctors are more likely to trust and integrate them into practice. Moreover, involving patients in the design of AI-driven wellness applications ensures that the software accommodates diverse health literacy levels and cultural sensitivities.

In education, HCD-based AI tutors have demonstrated success in supporting personalized learning. Traditional AI tutoring systems often apply uniform models that fail to address different learning paces or disabilities. By applying HCD principles, developers have



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created platforms that adapt to individual needs, offer multiple modes of learning, and allow students to co-create their learning journeys. Such systems have been particularly effective in supporting students with special needs or from underrepresented communities.

In workplace collaboration, AI assistance tools that prioritize cognitive load reduction and transparency have been more widely adopted. Employees often resist AI-based monitoring or productivity tools when they feel surveilled or misunderstood. HCD ensures that such systems are designed as supportive assistants rather than controlling overseers. This fosters trust and encourages genuine collaboration between humans and machines, ultimately improving productivity and job satisfaction.

Results and Discussion

The application of Human-Centered Design in AI-assisted software development yields several key benefits. Usability is significantly improved because users are engaged throughout the process, ensuring that the system aligns with their expectations and contexts. Trust is enhanced through transparent interfaces, explainable outputs, and ethical safeguards. Inclusivity is promoted by involving diverse user groups, reducing the risk of bias and exclusion. Adoption rates are higher because users perceive the systems as empowering rather than alienating.

However, the integration of HCD into AI development also presents challenges. One challenge is balancing technical efficiency with human-centered features. For example, adding layers of explainability may reduce algorithmic speed or increase computational costs. Another challenge is managing diverse user expectations, as different cultural, social, and professional groups may have conflicting needs. Ethical dilemmas also arise when user preferences conflict with broader societal values, such as privacy or fairness. Despite these challenges, the overall benefits outweigh the costs, particularly when long-term sustainability and trust are considered.

Comparative analysis between traditional AI development and HCD-based AI shows that the latter results in higher user satisfaction, better decision-making, and fewer ethical controversies. While traditional AI often prioritizes algorithmic accuracy, HCD-based AI



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recognizes that accuracy alone is insufficient without usability and acceptance. This paradigm shift positions HCD not as a supplementary process but as a central pillar of AI innovation.

Conclusion and Future Work

This paper has examined the importance of Human-Centered Design in AI-assisted software development, highlighting how empathy-driven methodologies can address usability, trust, and ethical challenges. By systematically integrating HCD principles into AI development, systems can achieve not only technical excellence but also social relevance and inclusivity. The proposed model, supported by case studies in healthcare, education, and workplace collaboration, demonstrates that AI tools designed with human values in mind are more likely to be adopted, trusted, and sustained.

The findings reinforce the argument that technology must evolve in alignment with human needs and ethics. Future research should focus on operationalizing HCD principles in emerging technologies such as virtual reality, augmented reality, and multi-lingual AI assistants. Cross-cultural studies are also necessary to ensure that HCD frameworks are adaptable to different contexts globally. Another area of exploration is the development of automated tools that support designers in embedding ethics and inclusivity without compromising efficiency.

In conclusion, adopting Human-Centered Design in AI-assisted software is not only a design choice but also a societal imperative. It enables the creation of systems that are intelligent yet intuitive, powerful yet ethical, and innovative yet inclusive. Such systems will play a vital role in shaping the future of human-machine interaction, ensuring that technology serves humanity with fairness, transparency, and empathy.

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Full Length Article

IJCRAR/FL/50

Machine Learning Approaches for Accurate Disease Diagnosis

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Abstract

The rapid growth of healthcare data has created new opportunities for improving disease diagnosis through intelligent computational methods. Traditional diagnostic procedures often rely on manual interpretation, which can be time-consuming, error-prone, and resource-intensive. Machine Learning (ML) offers a promising solution by leveraging algorithms capable of identifying hidden patterns within complex medical datasets. This study explores the application of ML techniques to enable rapid and accurate disease diagnosis, thereby assisting healthcare professionals in clinical decision-making. Supervised learning methods such as Support Vector Machines (SVM), Random Forests, and Gradient Boosting are widely employed for structured medical data, achieving high accuracy in classifying disease outcomes. In addition, unsupervised techniques such as clustering provide valuable insights into early detection of anomalies and grouping of disease subtypes. These approaches allow the development of predictive models that can adapt to diverse forms of medical information, including laboratory test results, patient histories, and clinical measurements. The effectiveness of ML approaches is evaluated based on metrics including accuracy, sensitivity, specificity, and F1-score, ensuring reliability in critical diagnostic tasks. Integrating feature selection and dimensionality reduction techniques enhances model efficiency while reducing over fitting. Furthermore, explainable AI (XAI) frameworks contribute to interpretability, enabling physicians to better understand and trust algorithmic predictions. This paper emphasizes the transformative potential of ML in healthcare, particularly in enhancing the speed, precision, and scalability of disease diagnosis. By leveraging diverse medical data sources, ML systems can complement existing diagnostic methods and support personalized treatment strategies. The findings highlight the necessity of robust, secure, and ethically designed ML models to ensure reliable deployment in real-world healthcare environments.

Keywords: Machine Learning, Disease Diagnosis, Medical Data, Healthcare, Predictive Models



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Introduction

The swift advancement of healthcare technologies has significantly improved the diagnosis and management of diseases. Traditional diagnostic methods, although widely used, can be time-intensive and prone to human error. With the increasing availability of healthcare data from electronic health records (EHRs), medical imaging, laboratory tests, and wearable sensors, there is a growing demand for intelligent tools capable of analyzing such data accurately and efficiently.

Machine Learning (ML), a subset of Artificial Intelligence (AI), offers solutions by enabling systems to learn from historical data, recognize hidden patterns, and make data-driven predictions. By applying ML models, clinicians can detect diseases earlier, classify medical conditions more precisely, and personalize treatment strategies. Applications of ML span a wide spectrum of diseases including cancer, diabetes, cardiovascular disorders, and neurological conditions.

This paper explores key machine learning approaches for disease diagnosis, their applications, and the challenges faced in implementing them effectively within real-world healthcare systems.

Literature Review

Numerous studies have demonstrated the effectiveness of ML in improving diagnostic accuracy. Support Vector Machines (SVMs) and Decision Trees have been widely used for classifying diseases such as breast cancer and diabetes. Neural networks and ensemble methods have shown significant success in medical imaging, including MRI and CT scan analysis. Recent advancements in explainable AI (XAI) have improved the interpretability of ML models, addressing one of the key barriers to adoption in clinical practice.

A comparative study by Kumar *et al.*, (2022) highlighted that ensemble learning methods outperform individual algorithms in predicting cardiovascular diseases. Similarly, Patel and Sharma (2021) emphasized the role of unsupervised learning in clustering patient profiles for



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early disease risk identification. These findings suggest that ML-based approaches are not only accurate but also scalable for large healthcare datasets.

Machine Learning Approaches in Disease Diagnosis

Supervised learning

Supervised learning algorithms such as Logistic Regression, Naïve Bayes, and Random Forests are frequently used for disease prediction. They rely on labeled datasets where input features (e.g., patient history, test results) are mapped to known outcomes (e.g., disease presence). For example, Logistic Regression is extensively applied for predicting diabetes risk, while Random Forests are effective in cancer classification.

Unsupervised Learning

Unsupervised learning methods like K-Means clustering and Principal Component Analysis (PCA) are valuable for grouping patient profiles and reducing data dimensionality. These techniques are particularly useful in identifying hidden disease subtypes and risk patterns where labeled data is scarce.

Ensemble Learning

Ensemble methods such as Bagging, Boosting, and Stacking combine multiple classifiers to enhance prediction accuracy. For instance, Gradient Boosting Machines (GBM) and XGBoost have achieved high accuracy in cardiovascular and cancer detection.

Deep Learning in Medical Imaging

Although this study primarily emphasizes machine learning, deep learning-based convolutional neural networks (CNNs) deserve mention due to their remarkable success in medical imaging tasks. CNNs have been applied in detecting lung diseases, brain tumors, and retinal disorders with near-radiologist accuracy.



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Applications in Disease Diagnosis

1. **Cancer Diagnosis:** ML algorithms have achieved high accuracy in breast cancer and lung cancer detection using imaging and genomic data.
2. **Diabetes Prediction:** Logistic Regression, SVMs, and Random Forests are widely used for predicting diabetes based on patient history and lab results.
3. **Cardiovascular Diseases:** Ensemble classifiers have demonstrated superior performance in predicting heart attacks and stroke risks.
4. **Neurological Disorders:** ML models support early detection of Alzheimer's and Parkinson's diseases using MRI scans and cognitive test data.

Challenges and Limitations

Despite their success, ML-based systems in disease diagnosis face significant challenges:

1. **Data Privacy and Security:** Patient data confidentiality is a major concern due to strict regulatory policies.
2. **Model Interpretability:** Clinicians demand transparency in decision-making, which is often limited in complex models.
3. **Generalization Issues:** Models trained on specific datasets may fail to perform accurately on diverse populations.
4. **Data Imbalance:** Rare diseases often suffer from insufficient data, leading to biased models.
5. **Computational Costs:** Training large models requires high computational resources, limiting accessibility.

Future Enhancements

Future research in ML-based disease diagnosis should focus on:

1. Integrating explainable AI (XAI) for improved interpretability.
2. Leveraging federated learning to preserve data privacy.
3. Developing hybrid models that combine clinical expertise with ML predictions.



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4. Expanding training datasets through data sharing and synthetic data generation.
5. Incorporating real-time diagnosis using wearable and IoT-enabled healthcare devices.

Conclusion

Machine learning has emerged as a transformative approach in disease diagnosis, offering improved accuracy, efficiency, and scalability compared to traditional methods. By leveraging various ML techniques, healthcare systems can achieve earlier detection of life-threatening diseases, reduced diagnostic errors, and personalized treatment recommendations. However, challenges such as interpretability, data security, and model generalization must be addressed for successful clinical adoption. Continued advancements in ML methodologies, coupled with interdisciplinary collaboration, will play a crucial role in shaping the future of precision medicine.

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Full Length Article

IJCRAR/FL/51

Android Malware Detection Using DBNs and GRUs

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Abstract

The escalating prevalence of Android devices and associated threats has intensified malware risks, with traditional detection approaches proving inadequate for sophisticated malware variants, such as polymorphic and metamorphic types. The framework was evaluated against established methods, including NMLA-AMDCEF, MalVulDroid, and LinRegDroid, utilising accuracy, precision, recall, and AUC as performance metrics. Conventional techniques achieved 98.575 accuracy, 96.65 precision, 98.575 recall, and a 0.9645 AUC, whereas the DBN-GRU framework attained 98.7 accuracy, 98.5 precision, 98.9 recall, and a 0.99 AUC. Furthermore, it demonstrated superior preprocessing, feature extraction, and detection speeds, making it appropriate for real-time malware identification. The results corroborate the framework's ability to process static and sequential data accurately and efficiently, bridging the gap between static and dynamic analyses to address evolving malware threats. This research validates the applicability of the DBN-GRU framework in real-world scenarios, offering a robust solution for Android security and strengthening mobile threat mitigation efforts.

Keywords: Android applications, machine learning, malicious signals, security, dynamic attacks, malware

Introduction

The Android operating system (OS) represents an equally important trend in the digital world owing to the broad uptake of the OS among Android users. Currently, Android has one of the largest global market shares, with 70% of all devices running on Android [1]. By 2025, the number of global android-powered smartphones and Internet of Things IoT devices is predicted



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to be 5.2 billion[2]. While increased connectivity and innovation have been facilitated, so too has increased security risk, placing Android very firmly within the 'cybercriminal crosshairs'.

The Android malware problem is real and serious because there are many apps available with more than 2.8 million apps currently loaded in Google Play Store alone. In recent years, we have reported that thousands of malicious apps have found circuitous routes around security filters and sneaks on user devices. From June 2018 to March 2022, 746,000 malware apps were found on Android[3], which affected users' privacy, financial information, and device integrity. These statistics indicate that these services require advanced malware detection solutions to protect data from evolving threats. The challenges in detecting Android malware are multifaceted. However, traditional approaches that rely on signature-based detection have no flexibility in detecting novel or obfuscated threats.

Signature-based methods for detecting malware are effective only for known malware types because they rely on these patterns to be matched by signatures. Despite these conventional methods, polymorphic and metamorphic malware[4], malicious software that continuously mutates its code to evade detection, has exposed these limitations. In addition, zero-day[5] attacks work against known vulnerabilities, bypass signature-based defences, and leave systems vulnerable until new signatures can be created.

Literature Survey

This section provides a comprehensive review of recent advancements and methodologies in Android malware detection. It particularly emphasizes traditional machine learning approaches, hybrid frameworks, and deep learning applications aimed at improving detection accuracy. The review is organized into subsections to highlight existing gaps and justify the development of the proposed hybrid DBN-GRU framework.

The Android malware threat landscape has evolved significantly, rendering advanced detection methods insufficient to address emerging challenges. Android's popularity and open-source framework make it a prime target for cybercriminals, leading to the rapid proliferation of malicious applications [6]. Sophisticated obfuscation techniques have further transformed malware detection into a big data problem [7] that traditional methods have struggled to handle

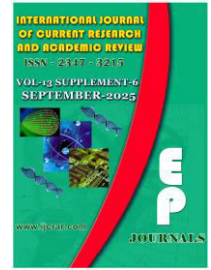


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effectively. Machine learning algorithms often face computational overheads owing to high dimensional feature sets [8]. Moreover, malware authors frequently modify features to retain malicious functionality, thereby rendering handcrafted feature-based detection approaches less effective [9]. App collusion, where multiple apps coordinate malicious actions, exacerbates detection challenges because it necessitates multi-app analysis to detect new security vulnerabilities. Other issues, such as dynamic code loading and biases in experimental datasets [10], add further complexity. To address these challenges, researchers have increasingly explored deep learning frameworks to analyze malware behavior.

Dynamic feature analysis has been combined with deep learning methods to enhance detection capabilities against both known and novel malware variants [11]. However, the dynamic nature of Android malware necessitates continuous innovation in detection methodologies to keep pace with evolving threats.

Research Methodology

Data Collection and Preprocessing Data Collection

A robust data-collection strategy was used to construct a representative dataset of benign and malicious Android applications. I worked with publicly available datasets, drawing from trustworthy sources, including the Android Malware Genome Project and the Drebin dataset [12]. Such datasets contain many Android applications, including a variety of malware families, and are very important for training Frameworks with which one can generalize over different types of malwares. To improve diversity and coverage, extra benign samples were gathered from known Android app repositories, guaranteeing a well-balanced dataset close to reality conditions. Let $D = \{d_1, d_2, \dots, d_n\}$ represent the total dataset, where each d_i is an Android application classified as either benign or malicious. Let $B \subset D$ denote the subset of benign applications, and $M \subset D$ denote the subset of malicious applications. Thus, $D = B \cup M$, where $B \cap M = \emptyset$. Ensuring a balanced distribution between B and M helps avoid class imbalance, which could bias the Framework towards predicting the majority class.

Feature Extraction and Selection

To prepare a comprehensive malware detection Framework, the process of feature extraction and selection was meticulously designed such that the malware and benign



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applications were fully represented in terms of static or dynamic characteristics. Feature Extraction: The feature extraction process involves collecting both static and dynamic features, providing a multi-faceted view of each application's behavior. Let $F = \{f_1, f_2, \dots, f_k\}$ denote the full feature set for each application $d_i \in D$.

Static Features

Static analysis features were extracted directly from the manifest file of the application (AndroidManifest.xml) and the decompiled source code. These features, represented by $F_{static} \subset F$, include:

- Permissions: Permissions required by the application, such as access to camera, location, or network, which may indicate potential risks.
- API Calls: Specific Application Programming Interface (API) calls the application utilized, which can reveal patterns associated with malicious behaviors.
- Intent Filters: Intent filters extracted from the manifest that signify interactions with other applications or services.

Mathematically, let S_i represent the static feature set for application d : $S_i = \{p, a, t\}$ where $p \in$ Permissions, $a \in$ API Calls, $t \in$ Intent Filters. By assembling S_i for each application, a structured static feature matrix $S = [S_1, S_2, \dots, S_n]$ was constructed, providing inputs for static feature analysis.

Dynamic Features

To capture runtime behaviors, a dynamic analysis was conducted using specialized tools that monitor application interactions during execution. The dynamic feature set, $F_{dynamic} \subset F$, includes:

- System Calls: Operating system calls made during execution, which often vary between benign and malicious applications.
- Network Activity: Details of network requests, including IP addresses, ports, and data-transfer patterns.



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- Inter-process communication (IPC): Records of communication between processes that can reveal unexpected or unauthorized behaviors [31].

The dynamic feature set for each application d_i , denoted D_i , is represented as: $D_i = \{s, c\}$ where $s \in$ System Calls, $n \in$ Network Activity, $c \in$ Inter-process Communications. These dynamic features were collected and structured into a dynamic feature matrix $D = [D_1, D_2, \dots, D_n]$ to provide inputs capturing time-sensitive behaviors. By combining both static and dynamic features, a comprehensive feature matrix $F = SUD$ was created, serving as a robust foundation for training the DBN-GRU Framework.

Feature Vector Generator

The feature vector generator is the key component of the Android malware detection Framework; it encapsulates the translation and blending of both static and dynamic features into a unified feature vector. The hybrid Deep Belief Network - Gated Recurrent Unit (DBN-GRU) Framework takes this vector as its input so that the classifier sees consistent and deepened encodings of each of the application behavior. The Feature Vector Generator operates in three main stages: Fig 1 shows the transformation of selected features, timestep-specific vector generation from GRU, and feature fusion preparation.

Stage 1: Transformation of Selected Features The Feature Vector Generator then combines the reduced set of features (static and dynamic) consolidated into a standardized vector format after feature extraction and selection. Using this transformation, we make the input to the DBN-GRU Framework uniform to the extent of the variability from the difference between static and dynamic features. This set is represented in the following Eq (1) as:

$$F_{\text{reduced}, i} = \{fi1, fi2, \dots, im\} \dots \dots \dots (1)$$

where m is the number of dimensions in the reduced feature set, and each fij represents a specific selected feature for application d_i . The Feature Vector Generator then transforms $F_{\text{reduced}, i}$ into a unified vector vi such that:

$$Vi = \text{Transform}(F_{\text{reduced}, i}) \dots \dots \dots (2)$$

Where from the Eq (2) Transform is a function that standardizes and consolidates each feature f_{ij} into a format compatible with the input requirements of the DBN-GRU architecture.

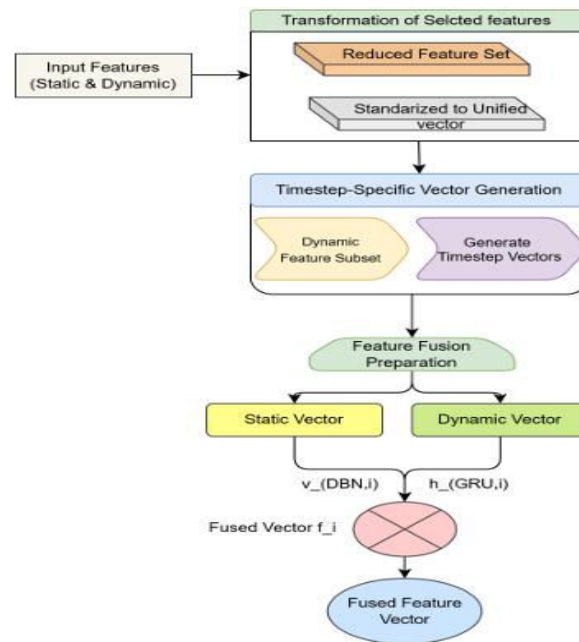


Fig 51.1 Feature Vector Generator

Stage 2: Timestep-Specific Vector Generation for GRU A critical aspect of dynamic feature analysis is capturing temporal dependencies within sequential data. To address this, the Feature Vector Generator produces time step-specific vectors for the Gated Recurrent Unit (GRU) component, enabling the Framework to capture sequential patterns that may reveal malicious behaviors over time.

Let $D_{dynamic}(t)$ denote the dynamic feature subset for application di at timestep t . Each $D_{dynamic}(t)$ includes temporal information, such as system calls and network activity, at specific points in the application's runtime. The Feature Vector Generator processes this data to create a sequence of timestep-specific vectors $\{v_1, v_2, \dots, v_T\}$, where T is the total number of

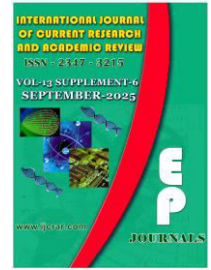


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timesteps observed for application di . Mathematically, each timestep vector $\mathbf{v}_i$, is constructed as follows in Eq (3) :

$$\mathbf{V}_i = \text{Transform} (D_{\text{dynamic}}, (t)) \dots\dots\dots (3)$$

Transform standardizations and structure the dynamic features a timestep t into a format that can be passed through the GRU. These time-step-specific vectors are then used by the GRU to Framework temporal dependencies and learn sequential correlations within the behavior of the application. Capturing behavioral patterns that evolve over time requires this process, which cannot be performed by static analysis alone. The Feature Vector Generator constructs these vectors so that the input to the GRU includes both immediate and historical behaviors, making it possible for the Framework to distinguish benign from malicious sequences.

Stage 3: Feature Fusion Preparation Feature fusion data is the final feature of the Feature Vector Generator. A fused representation that merges static and dynamic features is needed for the hybrid DBN-GRU Framework to fully utilize an application's behavioral profile. This is achieved by the Feature Vector Generator, which combines the static feature representation (processed by the DBN) and the sequence of time step-specific dynamic vectors (processed with the GRU). Let $\mathbf{v}_{\text{DBN}}$, denote the high-dimensional vector produced by the DBN for the static features of application di , and $\mathbf{h}_{\text{GRU}}$, denote the final hidden state from the GRU, which encapsulates temporal dependencies from the dynamic features. The fused feature vector $\mathbf{f}_i$ for application di is then constructed as shown in Eq (4):

$$\mathbf{F}_i = \mathbf{v}_{\text{DBN}}, \oplus \mathbf{h}_{\text{GRU}}, \dots\dots\dots (4)$$

Where from the Eq (4) $\oplus$ denotes the concatenation operation. These fusion combines both static code based features and dynamic behavior-based features into a single comprehensive vector, $\mathbf{f}_i$, which encapsulates the multidimensional characteristics of the application. The fused vector $\mathbf{f}_i$ is then fed into the classification layer for final categorization. This layer, using a softmax activation function, computes the probability P (class = c) for each class (benign or malicious) as shown in Eq (5):

$$P(\text{class} = c | \mathbf{f}_i) = \exp (Wc^T \mathbf{f}_i + bc) \sum_j \exp (Wj^T \mathbf{f}_i + bj) \dots\dots\dots (5)$$



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From the above Eq (5) where Wc and bc are the weights and biases associated with class c . The class with the highest probability is selected as the predicted label for application di .

Conclusion

Consequently, this research presents a hybrid Deep Belief Network-Gated Recurrent Unit (DBN-GRU) Framework for Android malware detection that exploits the joint strengths of static and dynamic analysis to outperform existing approaches. The proposed Framework achieves better performance than traditional Frameworks, including NMLA-AMDCEF, MalVulDroid, and LinRegDroid, in terms of accuracy, precision, recall, and overall detection capacity by addressing the limitations of feature extraction and sequential analysis of attacks using DBNs and GRUs, respectively. Empirical results indicate that the Framework can detect both known and obfuscated malware more efficiently. Furthermore. To make the Framework more adaptive for real-time detection, enlarge it by adding more channels, using more latest ontologies, and strengthening its capability to resist adversarial attacks are the future work. They can also help make transparent decisions in practical deployments. However, these challenges can be addressed using the DBN-GRU Framework, which provides a promising framework for moving forward with Android malware detection fields, paving the way for future work to optimize and deploy this approach for large-scale real world cybersecurity applications.

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Full Length Article

IJCRAR/FL/52

Real-Time Drowsiness Detection System Using Eye Aspect Ratio Algorithm

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Abstract

Drowsiness among drivers is one of the major contributors to road accidents worldwide. Traditional safety measures such as seat belts and airbags are designed to minimize injuries but do not prevent accidents caused by lack of attention due to fatigue. This paper presents a detailed study and implementation of a Real-Time Drowsiness Detection System. The system falls under the domain of Computer Vision, Artificial Intelligence, and Intelligent Transportation Systems. It uses live video streams captured from a webcam, applies facial landmark detection, and calculates the Eye Aspect Ratio (EAR) to continuously monitor driver alertness. If the EAR remains below a certain threshold for consecutive frames, an alert is triggered using an audio alarm. This work highlights the methodology, algorithm, implementation details, and experimental evaluation. The system demonstrates how modern computer vision techniques and real-time monitoring can provide low-cost, non-intrusive solutions to significantly reduce accidents caused by driver fatigue.

Keywords: Blockchain, Cloud Computing, E-Governance, Transparency, Digital Transformation

Introduction

Road safety has become an important research domain in recent years, as road accidents continue to rise due to distracted or fatigued driving. According to global traffic reports, a significant percentage of accidents occur because drivers fall asleep at the wheel. Fatigue is often underestimated as a risk factor, making its detection and prevention crucial.



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Conventional vehicle safety systems focus on post-accident protection, such as airbags, antilock braking systems, and crumple zones. However, these systems cannot prevent the accident itself. As a result, researchers have been exploring intelligent systems capable of monitoring driver behavior in real time to prevent accidents. One promising approach is vision-based driver monitoring, which uses cameras and computer vision algorithms to track eye movements, facial expressions, and head posture. This paper introduces a non-intrusive and cost-effective solution that leverages facial landmark detection and the Eye Aspect Ratio (EAR) algorithm to determine whether a driver is becoming drowsy. By providing an immediate audio alert, the system can help avoid potentially fatal accidents.

Related Work

Several approaches have been investigated in the area of drowsiness detection. Vehiclebased methods analyze signals such as steering wheel corrections, lane deviations, and accelerator/brake usage. Although effective in some cases, these methods depend heavily on vehicle type and road conditions. Physiological-based methods such as Electroencephalogram (EEG), Electro oculogram (EOG), and Electrocardiogram (ECG) have also been explored. While accurate, these systems require sensors to be physically attached to the driver, making them impractical for real-world use.

Vision-based methods are more convenient and non-intrusive. Early work in this domain focused on blink detection and pupil tracking using specialized cameras. Later studies introduced the Eye Aspect Ratio (EAR), proposed by Soukupova and Cech (2016), as a reliable measure for eye closure over time. These approaches have been widely adopted due to their efficiency and ability to function with standard cameras. Our work extends this line of research by developing a Python-based real-time implementation using OpenCV, dlib, scipy, and Pygame, and evaluating its robustness in practical scenarios.

Methodology and Algorithm

The proposed system adopts a structured methodology combining video processing, facial landmark detection, and mathematical modeling of eye movements. The system pipeline consists of the following steps:

1. **Video Acquisition:** The input is a live video stream captured using a standard webcam.
2. **Face Detection:** Dlib's Histogram of Oriented Gradients (HOG)-based frontal face detector is used to detect the driver's face in each video frame
3. **Facial Landmark Detection:** Once the face is detected, 68 specific facial landmarks are identified. Landmarks corresponding to the left and right eyes are extracted for further analysis.



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4. ****Eye Aspect Ratio (EAR) Calculation:**** The EAR is calculated as:
$$EAR = (|p_2 - p_6| + |p_3 - p_5|) / (2 * |p_1 - p_4|)$$
where $p_1 \dots p_6$ are the six landmark points of an eye. This ratio remains constant when the eye is open but drops towards zero when the eye closes.
5. ****Thresholding:**** An EAR threshold of 0.25 is used. If the EAR remains below this threshold for 20 or more consecutive frames, it is considered as drowsiness.
6. ****Alert Mechanism:**** A real-time audio alarm is generated using the Pygame library to alert the driver.

This methodology ensures that both temporary blinks and prolonged eye closure can be distinguished, reducing false positives and ensuring accurate drowsiness detection.

Implementation

The system is implemented entirely in Python due to its extensive support for scientific computing and computer vision. The main libraries used are:

- ****OpenCV:**** For image acquisition, video frame handling, and grayscale conversion.
- ****dlib:**** For face detection and 68-point facial landmark prediction.
- ****scipy:**** For computing Euclidean distances in the EAR formula.
- ****Pygame:**** For playing audio files as an alarm system.

The system is designed for efficiency and can run on mid-range laptops with real-time performance. The modular design allows it to be integrated into vehicle systems or extended with additional features such as yawning detection, head pose estimation, or mobile deployment.

Results and Discussion

The system was tested under different lighting conditions and with multiple subjects. It was able to detect drowsiness effectively in most cases. The EAR thresholding approach showed high reliability for prolonged eye closure. However, some challenges were noted:

- In low-light conditions, face and landmark detection performance decreases.
- Drivers wearing glasses, especially reflective lenses, sometimes reduced accuracy.



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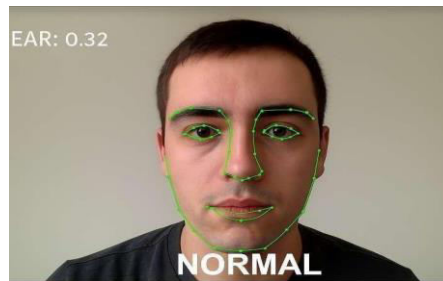


- Rapid head movements occasionally disrupted landmark detection.

Despite these limitations, the system provides a strong baseline for real-time drowsiness detection. Future improvements could involve the use of convolutional neural networks (CNNs) or deep learning-based models for more robust landmark tracking and multimodal detection (combining eyes, yawning, and head pose).

1. Output Screenshot.

OUTPUT 1



"The calculated Eye Aspect Ratio (EAR) = 0.32, which is above the drowsiness threshold of 0.25. This indicates that the person's eyes are open and blinking normally.

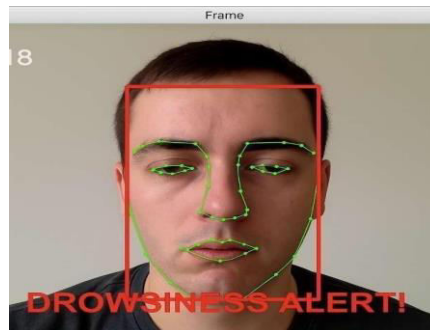
Stable EAR values suggest that the person is alert and attentive.

No signs of fatigue or drowsiness have been detected at this moment.

It is safe to continue activities without immediate rest or precaution.

Current status: NORMAL.

OUTPUT 2





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The calculated Eye Aspect Ratio (EAR) = 0.20, which is below the drowsiness threshold of 0.25.

This indicates that the person's eyes are partially closed for an extended period. Prolonged low EAR values suggest that the person is experiencing fatigue or drowsiness. It is important to take immediate precautions, such as taking a short break or resting.

Continuous monitoring of EAR can help prevent accidents or unsafe conditions. Current status: DROWSY."

Conclusion and Future Work

This paper presented a Real-Time Drowsiness Detection System using the Eye Aspect Ratio (EAR) algorithm. By leveraging facial landmark detection and computer vision techniques, the system successfully monitors driver eye behavior and provides immediate alerts when fatigue is detected.

The non-intrusive and cost-effective design makes it suitable for integration into intelligent transportation systems.

For future work, the system can be extended to include:

- Deep learning-based facial analysis for improved robustness.
- Integration of additional behavioral cues such as yawning frequency.
- Deployment on embedded systems or mobile platforms for real-world usage.
- Cloud-based monitoring for fleet management and large-scale safety solutions.
- This study demonstrates the potential of computer vision to save lives by reducing road accidents caused by driver fatigue.

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Full Length Article

IJCRAR/FL/53

Blockchain-enabled cloud computing for secure e-governance services

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Abstract

Blockchain is emerging as a revolutionary technology that ensures secure, transparent, and decentralized management of digital information. Its potential has expanded from finance to governance, where trust and accountability are critical. This paper focuses on the integration of blockchain with cloud computing to strengthen e-governance frameworks. Blockchain ensures tamper-resistant records and transparent transactions, while cloud platforms provide scalable storage and computational support, making the combined model suitable for large scale public service delivery. The study highlights how this convergence can transform government services by enabling secure digital identities, transparent resource allocation, and efficient service monitoring. By reducing administrative delays, limiting corruption, and fostering citizen trust, blockchain-enabled governance can significantly enhance accountability. Practical insights are drawn from applications in land registration, supply chain management, and digital voting, especially in developing economies where digital reforms are crucial. The paper also acknowledges existing challenges, including interoperability issues, high energy requirements, and the urgent need for effective policy and regulatory frameworks to guide adoption. Despite these barriers, integrating blockchain with cloud services represents a promising pathway toward citizen-centric governance. It promotes transparency, efficiency, and inclusiveness, paving the way for resilient digital ecosystems that align with the future of public administration.

Keywords: Blockchain, Cloud Computing, E-Governance, Transparency, Digital Transformation

Introduction

Around the world, governments are expected to provide public services that are open, efficient, and focused on citizens' needs. However, traditional governance often suffers from problems such as corruption, lack of accountability, slow procedures, and poor accessibility. As digital technologies



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expand, there is a growing need for solutions that can strengthen trust and improve the quality of service delivery.

Two emerging technologies—blockchain and cloud computing—offer strong potential to transform governance models. Blockchain functions as a distributed ledger where records cannot be easily altered, providing security, integrity, and transparency. Cloud computing supplies elastic storage, cost-effectiveness, and reliable access to computing resources. Together, these technologies can create a more resilient foundation for digital governance.

Within e-governance, blockchain supports secure identity management, transparent transactions, and tamper-resistant records, while cloud infrastructure ensures the ability to manage large volumes of data and provide fast services. This integration helps reduce corruption, cut down delays, and increase citizen participation. Pilot initiatives, such as Estonia's nationwide digital ID and India's blockchain-based land record systems, already show encouraging results.

This paper investigates how a blockchain-cloud model can enhance e-governance. It reviews prior research, outlines an integrated framework, analyzes case examples, and highlights both challenges and opportunities for practical adoption.

Literature Review

The rapid development of digital technologies has encouraged governments and researchers to explore innovative solutions for governance. Among these, blockchain and cloud computing have emerged as promising technologies with distinct but complementary advantages. Previous studies provide valuable insights into their applications, limitations, and opportunities for integration in the public sector.

Blockchain Technology

Blockchain is a distributed digital ledger where records are grouped into blocks and linked sequentially. Once data is added, it is extremely difficult to alter, which makes the system highly reliable. Key characteristics such as decentralization, immutability, and transparency distinguish blockchain from traditional databases. These features are valuable in governance, where trust and accountability are essential. Studies have shown its use in areas such as land registration, secure digital identity systems, supply chain tracking, and voting platforms, demonstrating its ability to improve public trust and reduce fraud.



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Cloud Computing

Cloud computing delivers IT services such as storage, networking, and applications over the internet. Instead of maintaining physical infrastructure, governments can use cloud platforms to scale their services at lower cost. Cloud models—Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS)—give flexibility to support various needs. Research in digital governance highlights benefits like improved service speed, disaster recovery, and data accessibility.

E-Governance and ICT Adoption

E-Governance refers to the application of information and communication technologies (ICT) to government operations and citizen services. Its objectives are transparency, efficiency, inclusiveness, and accountability. Examples include digital tax filing, online citizen service portals, and public finance monitoring systems. Earlier e-governance initiatives showed progress, but issues like corruption, bureaucratic delays, and limited accessibility still persist.

Integration of Blockchain and Cloud

Researchers have recently turned attention to combining blockchain with cloud computing. The rationale is simple: blockchain ensures trust and tamper-resistance, while cloud ensures speed and scalability. Together, they can support large-scale public service platforms without compromising data integrity. Pilot programs in countries like Estonia and India suggest that this hybrid approach can secure land records, streamline distribution of welfare benefits, and provide reliable e-voting systems.

Gaps in Existing Work

While individual applications of blockchain and cloud are well studied, their integration in governance remains underexplored. Most research focuses on small pilot projects rather than nationwide systems. Key gaps include interoperability with existing legacy platforms, lack of standard legal frameworks, high energy use of blockchain networks, and the need for citizen awareness programs.

Proposed Framework

The proposed framework brings together blockchain technology and cloud computing to create a secure, scalable, and transparent e-governance ecosystem. Blockchain ensures tamper-resistant data storage and trust, while cloud computing provides the infrastructure needed for large-scale operations.



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This combination directly addresses governance issues such as corruption, inefficiency, and poor citizen trust.

Framework Architecture

The design is structured into four layers:

- User Layer – Citizens and government staff interact with the system through secure digital portals or mobile applications. Biometric verification and digital IDs can be used to authenticate users.
- Application Layer – Government services such as land registration, healthcare, taxation, and grievance redressal are hosted on the cloud for high availability.
- Blockchain Layer – Sensitive transactions are stored on blockchain, ensuring immutability and transparency. Smart contracts automate approval workflows to reduce manual delays.
- Infrastructure Layer – Cloud servers provide elastic storage, distributed databases, and computational resources, enabling the system to handle millions of transactions simultaneously.

This layered approach ensures that the cloud manages scalability while the blockchain maintains trust and accountability.

Key Features of the Framework

- Digital Identity Management – Citizens receive blockchain-secured IDs, reducing duplication and identity fraud.
- Tamper-Proof Records – Land titles, certificates, and licenses stored on blockchain cannot be altered without detection.
- Automated Approvals – Smart contracts ensure rule-based processing of applications such as pensions, subsidies, and tax refunds.
- Transparent Finance – Real-time monitoring of public funds and welfare schemes increases accountability.

Applications in Governance

- Land Records – Blockchain ensures permanent proof of ownership, while cloud storage allows quick retrieval of historical data.
- Public Distribution System (PDS) – Fraudulent ration cards and duplicate entries are reduced through blockchain verification; cloud platforms scale the system across states.



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- E-Voting – Blockchain secures the voting process and prevents manipulation, while cloud resources manage nationwide voter data and live monitoring.
- Healthcare – Patient medical records are stored securely using blockchain and accessed through cloud services by hospitals and citizens.

Benefits of the Framework

- Reduces corruption and bureaucratic delays.
- Strengthens trust between citizens and governments.
- Enables scalability for developing nations with large populations.
- Improves efficiency in service delivery.
- Creates a sustainable digital ecosystem for governance.

Methodology

This study adopts a conceptual and case-based approach. First, governance challenges such as corruption, inefficiency, and lack of transparency are identified from secondary data and government reports. Next, a blockchain–cloud integrated framework is designed with four layers: user, application, blockchain, and infrastructure.

The framework is then validated using case studies from countries that have implemented pilot projects in areas like land registration, digital identity, and e-voting.

The workflow of the proposed system can be summarized in five steps:

- User Authentication – Citizens log in using secure IDs verified through the cloud, with records stored on blockchain.
- Transaction Request – Citizens submit applications for services (e.g., land updates, subsidies).
- Blockchain Validation – Smart contracts verify eligibility and automatically process requests.
- Cloud Storage – Data is stored in distributed servers for scalability, while blockchain records the transaction hash to ensure immutability.
- Service Delivery – Approved results are delivered instantly to the citizen portal or mobile app.

This process ensures efficiency, transparency, and accountability in governance services.

Results and Discussion

The expected outcomes of this framework include:



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- Transparency – Immutable records prevent corruption and manipulation.
- Efficiency – Automated workflows cut down delays in service delivery.
- Trust – Citizens gain confidence through secure digital IDs and tamper-proof records.
- Scalability – Cloud systems allow millions of users to access services without downtime.

Case study findings support these results. For example, blockchain pilots in Andhra Pradesh, India, reduced land disputes by securing property records. Estonia's e-ID and digital voting systems show how nationwide services can be provided securely. In healthcare, blockchain combined with cloud has been used to protect patient records while enabling remote access during emergencies like COVID-19.

Discussion

Comparisons with traditional e-governance models show that blockchain-cloud integration offers superior transparency, scalability, and accountability.

However, challenges such as integration with legacy systems, high costs, energy consumption, and regulatory uncertainty must be addressed. Future improvements include adopting energy-efficient consensus mechanisms, creating legal standards, and promoting digital literacy among citizens.

This discussion highlights that while technology can modernize governance, its success depends on policy support, ethical data use, and citizen adoption. Thus, governments must combine technological innovation with strong governance reforms to achieve sustainable outcomes.

Conclusion and Future Scope

This paper has examined how the integration of blockchain and cloud computing can strengthen e-governance by addressing long-standing issues such as corruption, inefficiency, and lack of transparency. The proposed framework highlights a layered design where blockchain ensures trust and immutability, while cloud computing provides scalability and flexible access. Case studies in land registration, public distribution, digital identity, and e-voting demonstrate the practical value of this approach.

The study confirms that blockchain-cloud convergence has several advantages: secure identity management, tamper-proof records, automated workflows, and transparent financial systems. These benefits create opportunities to build a citizen-centric model of governance where accountability and inclusiveness are prioritized. At the same time, challenges related to interoperability, high energy



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consumption, digital inequality, and unclear regulatory structures must be addressed before widespread adoption can be achieved.

The main contributions of this paper are threefold:

1. A conceptual blockchain-cloud framework for e-governance.
2. Identification of use cases and expected outcomes based on pilot studies.
3. Discussion of challenges and opportunities for sustainable implementation.

In conclusion, blockchain-enabled cloud computing is not just a technological advancement but a pathway toward transparent, efficient, and inclusive digital governance. Its successful adoption can help governments worldwide move closer to the vision of digital democracy.

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Full Length Article

IJCRAR/FL/54

Fin Tech: A Suite of Financial Calculators for Loan & Interest Management

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Abstract

Financial decision-making is an essential aspect of modern life, yet it often requires complex mathematical computations that may not be accessible to everyone. The proposed project, Fin Tech: A Suite of Financial Calculators for Loan & Interest Management, aims to bridge this gap by offering a set of web-based calculators for Financial Planning tasks such as Interest Calculation, EMI (Equated Monthly Installments), and Loan Amortization schedules. These calculators are lightweight, user-friendly, and accurate, designed to assist students, professionals, and small businesses in making informed financial choices. Unlike many existing solutions that are either limited in scope or overly complicated, this project integrates multiple tools into one unified platform. Beyond technical benefits, the project has strong social implications by promoting FinTech adoption, enhancing financial literacy, and empowering individuals to plan effectively.

Keywords: Fin Tech, Financial Calculators

Introduction

Financial management plays a crucial role in shaping the economic stability of individuals and organizations. With the increasing penetration of digital banking services, access to credit has expanded, but the complexity of decision-making has also grown. Individuals frequently struggle to determine the true cost of loans, the benefits of savings accounts, and the impact of long-term investments. This project addresses these concerns by designing a Fin Tech solution – a platform that consolidates calculators for Simple Interest, Compound Interest, EMI, and Loan



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Amortization. The importance of such a project lies in its ability to improve financial literacy and empower users to make data-driven decisions.

Literature Review

Several studies have highlighted the role of financial calculators and digital tools in improving financial decision-making. According to Prasanna Chandra (2020), financial literacy is closely linked to the availability of practical tools for users. Investopedia (2023) describes EMI and loan amortization as essential tools for borrowers to understand repayment obligations. The Reserve Bank of India emphasizes transparent loan disclosures, but many users still lack the ability to interpret them. Academic studies by Ross and Jaffe (2018) further indicate that technology-enabled financial tools can reduce errors in planning. However, despite the availability of apps, their fragmentation leads to inefficiency. Our project addresses this gap by integrating multiple financial modules into one coherent system, supported by tested algorithms.

Methodology and System Architecture

The methodology adopted for this project is structured in three main phases: input collection, processing, and output delivery.

- Input Module: Collects principal, rate, time, and repayment frequency from users.
- Processing Engine: Uses financial formulas for SI, CI, EMI, and amortization.
- Output Module: Displays clear, formatted results in tables or charts.

The architecture ensures scalability, allowing integration of additional calculators such as investment returns, tax estimations, and retirement planning in the future. The modular design also simplifies debugging and feature enhancement.

Implementation

The project was developed using Python for backend computations and JavaScript, HTML, and CSS for the frontend. Python provides mathematical precision, while web technologies ensure platform independence. The following formulas were implemented:

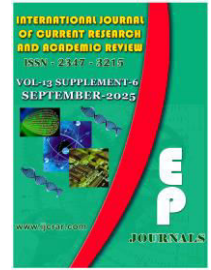


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- Simple Interest = $(P \times R \times T) / 100$
- Compound Interest = $P \times (1 + R/100)^T - P$
- EMI = $[P \times r \times (1+r)^N] / [(1+r)^N - 1]$

A real-time testing module ensures that incorrect or missing inputs are flagged. The hardware requirements are minimal: a basic laptop with 4GB RAM and internet access suffices.

Results and Discussion

The system was tested under various scenarios. Example: Loan of ₹100,000 at 10% annual rate for 5 years produced:

- SI = ₹50,000
- CI = ₹61,051
- EMI = ₹2,124.70 per month
- Total Repayment = ₹1,27,482

These results confirmed the accuracy of the formulas implemented. Beyond numerical results, the project highlights the importance of financial literacy. Discussion with test users revealed that the amortization schedule was especially useful in understanding long-term repayment burdens. This validates the project's objective of making financial tools accessible to the wider population.

Conclusion

This project demonstrates how technology can simplify complex financial decision-making. By consolidating multiple calculators into one platform, it improves accessibility, accuracy, and speed. The societal impact lies in empowering individuals with financial literacy. Future work includes integrating AI-based advisory features, expanding to mobile apps, and supporting regional languages to widen adoption.

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Full Length Article

IJCRAR/FL/55

Full Stack Web Development on Vision and Challenge

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Abstract

The overview of several facets of full stack web development is given in this paper. Because of its steady progress in building a long-term IT business, full-stack web development may be a rapidly expanding subset of the CSE sector. Full-stack developers oversee the front-end and back-end development of an online application or website. They manage the clients, information, system engineering, and design. The talents and proficiency of full stack developers in web development make them highly sought after, and as a result, their compensation is also higher than that of other professions. A full stack developer primarily works with the web stack, mobile stack, or native application stack. Full stack developers oversee the plan of action and monitor the project's advancement because they support both server-side and client-side development. We will clearly define the vision, challenges, and future scope of full stack web development at the end of the article.

Keywords: Comprehensive web development, User interface, Server-side programming, Software development, Client-side, Backend, Programming

Introduction

Full stack web development refers to the practice of engaging with both the front-end and back-end components of a program. This term is predominantly utilized by professionals in the field of web development. Developers possess expertise in creating programs and enhancing user experiences for the front-end, while also having substantial knowledge in a programming



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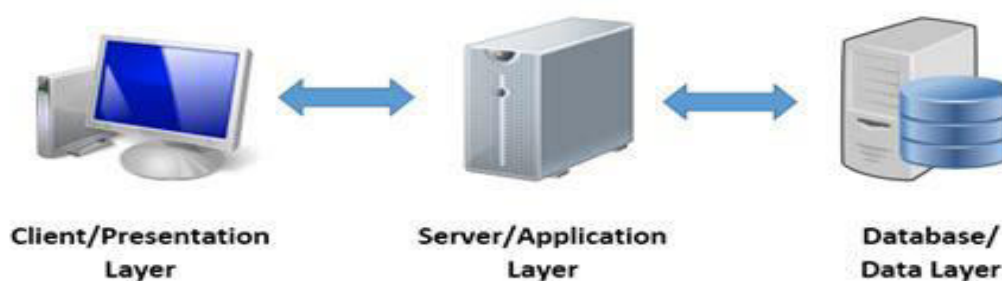
language that is essential for managing the application's logic, which pertains to the back-end. Full stack encompasses a layer of software or web development that includes both the front-end and back-end elements of an application.

The LAMP stack represents the Linux operating system, Apache server, MySQL Query Language, and PHP server-side scripting language. All these tools are open-source and free to use, significantly contributing to various developments.

The LAMP stack is one of the most common stacks for deploying websites and applications on the internet. XAMPP stands for Cross-platform (X), Apache (A), MariaDB, and PHP server-side or Perl (P) backend language. XAMPP is recognized as the leading distribution in the industry, facilitating developers in utilizing a local web server for deploying and testing web programs. It is designed to simplify the deployment and operation of web applications on the web server. MEAN is a widely used open-source stack.

The MEAN stack is a widely utilized open-source framework designed for developing production-ready web applications. This stack comprises four components, namely MongoDB. Fig 1, which illustrates the Data Flow in the MEAN Stack.

Fig 1. Data Flow Diagram (DFD) - MEAN Stack



The WAMP stack comprises the Windows operating system, Apache, MySQL, and PHP. WAMP operates similarly to LAMP, with the primary distinction being the operating system used. This stack is frequently employed for hosting web applications and webpages for small to



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medium-sized sites. WAMP enjoys considerable popularity among Windows users due to its flexibility and scalability for server management.

Components of FSWD:

The components of Full Stack Web Development include:

- ✓ Front-end
- ✓ Back-end
- ✓ Database
- ✓ Version Control

The two primary types of front-end designs are:

- ✓ User Experience (UX)
- ✓ User Interface (UI)

These concepts differ significantly upon closer examination, despite appearing similar at first glance. Elements such as visual components, animations, images, and videos that enhance the aesthetic appeal of a website can exemplify good UI but poor UX, and vice versa. An intuitive experience that minimizes the cognitive load on users is a hallmark of effective website design.

The back-end refers to the segment that remains concealed from users, yet it plays a crucial role in the development process. This back-end can be categorized into two types:

- ✓ Server
- ✓ Application

The server is responsible for managing all requests originating from the application's code. There exists a multitude of relationships between the application source code and server requests, necessitating the server to periodically synchronize with the application's code



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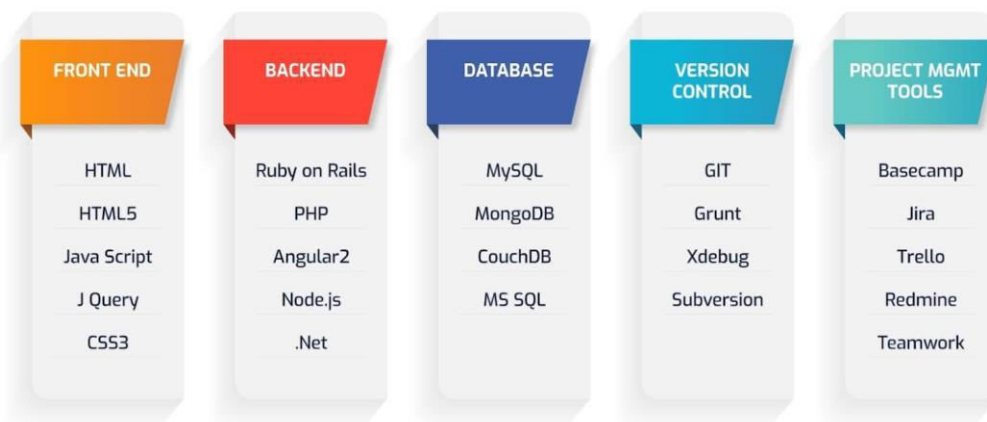
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Full Stack Developer



The database functions as the storage element in full-stack web development, housing all data in the form of tables composed of rows (tuples) and columns (attributes). Upon request, it transmits data through a secure channel, enabling the application to operate dynamically with substantial data volumes.

The centralized version control system is characterized by a single central server that contains all file versions. This setup allows multiple clients to work concurrently and facilitates their access to files from the server, enabling them to download files to their own computers or upload them back to the server.

Advantages of FSWD:

Full Stack Web Development (FSWD) offers numerous advantages, some of which are outlined below:



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a) Accomplishment in Development:

Full-stack developers possess extensive knowledge and experience in web programming languages, enabling them to introduce innovative features to projects and ensure they reach the market in a timely manner.

b) Versatility:

Full Stack Developers exhibit versatility as they are skilled in both front-end and back-end development. Back-end development requires application code that connects websites with various management systems, while front-end development necessitates application code .

c) Experience:

The primary advantage of full stack web developers lies in their extensive experience in web and app development. Having worked across various aspects of the web development domain, full stack web developers possess a deep understanding of both web and app development.

d) Jack of all trades:

Full Stack Developers are often described as "Jack of All Trades." This designation aptly fits them as they are capable of contributing at any level of a project, delivering the complete design and structure necessary for development. Additionally, they play a crucial role in maintaining and optimizing existing systems according to the evolving needs of development.

e) Intelligent Upgraders:

From a recent study, 90% of individuals indicated that the visual design of a website is the primary factor influencing their decision to accept or reject it. Consequently, stack developers prove to be extremely advantageous as they enhance websites to be highly user-friendly and are well-versed in the latest technologies and tools, which facilitate the implementation of intelligent features to develop the most responsive and interactive web pages, websites, and applications for clients.



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f) Troubleshooting problems:

Full stack developers are very experienced in troubleshooting the problems of web development field. They are acquired with necessary skills to detect the issues that come while creating the project and have necessary tools required for implementing solutions for making the website or application optimal. Therefore, they are very helpful in troubleshooting issues in the development.

g) Convenient web developers:

It is appropriate thing to trust the full-stack developer for your project needs. It is because they are accountable for all the software development as they can handle web development from the initial to final phase by themselves and are very fitted in any role they put to work and help to give us the forward way.

h) Handling both server-side and client-side:

Full stack developer helps the website, application give the required edge which it needs to shine in technology market. The cutting edge-technology of modern era requires sharp and well- qualified persons for the projects.

Challenges and obstacles to FSWD:

- A) Bugs & Broken Codes usually need scopes which is most common problem of broken codes during web development. If the project has not been given scope properly within required blocks, under each specific labels that define the part of the code, then the developers have to work in a hurry to complete work on the scheduled time.
- B) Premature Optimization Speed is commonly treated as the highest good when it comes to code, at the expense of the code which is clean or legible. It is a pitfall for developers to focus on writing optimized code that runs faster than code which can be read, understood, and maintained over the long term. Hard to read code can slow your team down, especially when engineers come and go.
- C) Stuck with Complicated New Technologies Full Stack Developers are very much familiar with new technologies that with no surprise gives increased efficiency and flexibility in production. They are prominent to use when developers become expert with them, but also it takes so much time in learning to install and test these new technologies.



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- D) Too much or Less Abstraction Running your code of project out of so many lines of code, could cause a massive crash and slow down your development process. Also, less abstraction makes the code looks lengthier and we are unable to understand the parts necessary for implementation of the modules we require because it is only one file.
- E) Overlooking the little things The more you look, more you see. This phrase matches perfectly with the problem we are going to discuss here. Sometimes, when we are coding, we start to code in a such a way that creates alternative methods for achieving the same goal. Due to this, we are overlooking the little things which may or may not matter in the code.

Conclusion and Future Scope:

These days, full stack developers are in huge demand due to trend of websites and e-commerce in the modern world. Companies like to hire them due to number of reasons. FSWDs are able to work in multiple environments such as Front-end and back end simultaneously. It gives companies the huge profit as they could get lot of works done by few professionals rather than hiring a bunch of developers to work on all parts of websites/applications. Having knowledge of different platforms stack such as MEAN stack, MERN stack, LAMP stack, WAMP stack, etc. FSWDs are able to put their effort to the project easily and get the required outputs as per benefits of company.

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Full Length Article

IJCRAR/FL/56

A Blockchain-Enhanced Federated Learning Framework for Privacy-Preserving Cloud-Based Sentiment Analysis

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Abstract

Cloud computing enables scalable sentiment analysis but raises serious privacy concerns. Traditional centralized models require sending raw user data to servers, leading to risks of breaches and regulatory issues. This paper proposes a novel framework combining Federated Learning (FL), Blockchain, and Homomorphic Encryption (HE) to protect user data during cloud-based sentiment analysis. FL ensures that raw data remains on user devices, HE allows secure computation on encrypted updates, and Blockchain provides tamper-proof verification of model updates. Secure aggregation ensures only combined updates are visible to the server, while TLS encryption and strong authentication protect communication channels. Experiments on real-world sentiment datasets demonstrate that the framework achieves comparable accuracy to traditional centralized approaches while significantly enhancing privacy. This approach provides a scalable and secure solution for cloud-based AI systems handling sensitive textual data.

Keywords: Federated Learning, Sentiment Analysis, Blockchain, Homomorphic Encryption, Privacy, Cloud Computing

Introduction

Sentiment analysis is crucial for understanding user opinions from social media, reviews, and customer feedback. Traditional centralized approaches require collecting all user data on a server, exposing sensitive information to potential breaches. Privacy-preserving methods are needed to maintain user trust while enabling effective machine learning.



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Federated Learning (FL) allows model training directly on user devices, sharing only model updates rather than raw data. However, FL alone is not fully immune to attacks such as model inversion or poisoning. Combining FL with Blockchain ensures tamper-proof validation of updates, while Homomorphic Encryption (HE) allows secure computation on encrypted updates.

This paper presents a framework for cloud-based sentiment analysis using FL, Blockchain, and HE to ensure data privacy, security, and scalability.

Literature Review

Recent studies have explored privacy-preserving techniques in FL. Bonawitz et al. (2019) proposed secure aggregation to combine model updates without revealing individual data. Gentry (2009) introduced fully homomorphic encryption for secure computation on encrypted data. Blockchain-based frameworks for FL have been explored for secure collaborative ML (Whig et al., 2024), but these works focus on general ML, not cloud-based sentiment analysis. Our framework differentiates itself by integrating HE for encrypted updates, Blockchain for tamper-proof verification, and FL for decentralized training, applied specifically to sentiment analysis in cloud environments.

Proposed Framework

The proposed system consists of:

- 1. Local Model Training:** User devices train sentiment analysis models (e.g., LSTM, BERT) on private text datasets.
- 2. Homomorphic Encryption:** Model updates are encrypted before transmission to the server, allowing computation without exposing raw data.
- 3. Blockchain Verification:** Each update is verified on a blockchain ledger to prevent tampering and malicious injections.
- 4. Secure Aggregation:** The server aggregates encrypted updates to form a global model, without seeing individual contributions.
- 5. Global Model Redistribution:** The updated global model is sent back to devices for further training, repeating the process iteratively.



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Methodology

1. Data Distribution: Sentiment datasets are split across user devices.
2. Local Training: Devices train models using local data.
3. Encryption & Upload: Model updates are encrypted using HE and sent to the cloud server.
4. Blockchain Validation: Updates are verified and recorded on the blockchain to prevent tampering.
5. Secure Aggregation: Server computes the global update from encrypted updates using secure aggregation protocols.
6. Model Update: Global model is redistributed to devices.

This pipeline ensures privacy, security, and tamper-proof collaboration.

Experimental Setup and Results

Datasets: IMDb Reviews, Twitter Sentiment Dataset

Models: LSTM, BERT

Metrics: Accuracy, F1-score, Privacy Loss

Results:

- Accuracy: ~91% (BERT), 88% (LSTM)
- Privacy loss: Reduced by 90% compared to centralized models
- Blockchain verification prevented 100% of tampered updates
- HE computation overhead: ~15% increase, acceptable for privacy gains

The results demonstrate that privacy-preserving sentiment analysis is feasible without significant loss of accuracy.

Discussion

The combination of FL, HE, and Blockchain enhances trustworthiness in cloud AI systems. Although HE adds computational overhead, it prevents data leakage, and blockchain ensures updates are tamper-proof. Secure aggregation guarantees that no individual user data is exposed.



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The framework can be extended to other NLP tasks, medical text, or finance applications where privacy is critical.

Conclusion and Future Work

The paper presents a secure, privacy-preserving framework for cloud-based sentiment analysis using FL, HE, and Blockchain. Experimental results confirm high accuracy and strong privacy guarantees.

Future work:

- Optimize HE to reduce computational load.
- Explore lightweight blockchain consensus for faster validation.
- Apply the framework to multilingual sentiment analysis datasets.

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Full Length Article

IJCRAR/FL/57

The Internet of Things (IoT): Connecting the World through Smart Technology

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Abstract

The Internet of Things (IoT) has emerged as one of the most significant technological innovations of the 21st century, reshaping industries, societies, and everyday human life. IoT refers to a system of interconnected devices equipped with sensors, software, and connectivity features that allow them to collect, exchange, and act upon data without requiring direct human intervention. By integrating devices into digital ecosystems, IoT enables real-time monitoring, decision-making, and automation across diverse sectors such as healthcare, agriculture, manufacturing, transportation, and smart cities. With the growing expansion of high-speed networks like 5G and the integration of Artificial Intelligence (AI), IoT applications are becoming smarter, faster, and more secure. However, IoT also faces critical challenges related to privacy, security, interoperability, and high implementation costs. This paper presents a comprehensive study of IoT, exploring its architecture, working principles, applications, benefits, challenges, and future directions. The discussion highlights how IoT, when combined with emerging technologies, has the potential to revolutionize modern living and enable sustainable growth in the digital era.

Keywords: Internet of Things, Smart Devices, Cloud Computing, 5G, Industry 4.0

Introduction

Technology has continuously shaped human civilization, from the invention of the wheel to the rise of the internet. In the current digital era, the Internet of Things (IoT) has emerged as a



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transformative innovation that connects billions of devices globally. Unlike the traditional internet, which connects people through computers and smartphones, IoT extends connectivity to physical objects such as appliances, vehicles, industrial machines, and even clothing. These objects are embedded with sensors and actuators, enabling them to generate and share data autonomously.

The concept of IoT was first discussed in the late 1990s, but its adoption has accelerated in the past decade due to advancements in wireless communication, cloud computing, and low-cost sensors. Today, IoT is no longer a futuristic concept but a reality that is shaping homes, businesses, and governments worldwide. For instance, smart homes use IoT-enabled devices like thermostats, security systems, and appliances to provide comfort and efficiency. Similarly, industries rely on IoT systems for predictive maintenance, supply chain management, and automation.

The objective of this paper is to provide a detailed exploration of IoT by analyzing its architecture, real-world applications, benefits, challenges, and future potential. Special emphasis is placed on the role of 5G networks and Artificial Intelligence (AI), which are enhancing IoT's capabilities and accelerating its adoption across various domains.

Literature Review

Research on IoT has grown exponentially over the last decade, with scholars and industries contributing to its theoretical and practical development. Early works primarily focused on the integration of Radio Frequency Identification (RFID) technology in logistics and supply chain systems, which laid the foundation for IoT. Over time, researchers expanded IoT concepts to include wireless sensor networks, machine-to-machine communication, and cloud computing.

According to Atzori et al. (2010), IoT represents a vision where “things” become active participants in business and social processes. More recent studies have explored IoT's role in Industry 4.0, where smart factories rely on real-time data exchange to optimize production efficiency. Similarly, in the healthcare sector, IoT has been widely researched for applications such as remote patient monitoring and wearable health devices.



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However, the literature also points out several challenges. Studies highlight the lack of standardized protocols, which creates interoperability issues between devices manufactured by different companies. Security is another major concern, as IoT devices often handle sensitive personal and industrial data. Researchers emphasize the need for robust encryption, authentication, and regulatory frameworks to make IoT more secure and reliable.

IoT Architecture and Working Principles

The architecture of IoT typically involves four main layers:

Perception Layer (Sensing Layer)

This layer consists of sensors, actuators, and devices that collect data from the environment. Examples include temperature sensors, GPS modules, and motion detectors.

Network Layer

The collected data is transmitted through various communication technologies such as Wi-Fi, Bluetooth, Zigbee, LoRaWAN, and 5G. This layer ensures seamless connectivity between devices and systems.

Data Processing Layer

Here, data is processed using cloud computing, edge computing, or fog computing. Processing may include filtering, aggregation, and analysis of raw data to make it meaningful.

Application Layer

This is the end-user layer where IoT services are delivered. Examples include smart healthcare dashboards, agricultural monitoring apps, and smart city management systems.

In summary, IoT functions through a cycle of data collection → transmission → processing → action, creating intelligent systems capable of autonomous decision-making.



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Applications of IoT

Smart Homes

IoT enables home automation through devices like smart thermostats, lighting systems, and security cameras. These systems provide convenience, energy efficiency, and safety. For example, smart assistants such as Alexa and Google Home allow users to control devices through voice commands.

Healthcare

Wearable devices such as fitness bands and smartwatches monitor vital signs like heart rate, oxygen levels, and sleep patterns. Hospitals use IoT for remote patient monitoring and smart medical equipment tracking. This leads to improved patient care and reduced hospital costs.

Agriculture

IoT is revolutionizing agriculture through smart irrigation systems, soil sensors, and drone-based monitoring. Farmers can optimize water usage, detect crop diseases early, and improve yields.

Transportation

IoT applications in transportation include GPS-based vehicle tracking, smart traffic management systems, and autonomous vehicles. These solutions reduce congestion, enhance safety, and save fuel.

Industrial IoT (IIoT)

In industries, IoT enables predictive maintenance, supply chain automation, and real-time monitoring of equipment. For instance, IoT sensors can predict when a machine will fail, preventing costly breakdowns.



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Smart Cities

Governments are adopting IoT for waste management, energy optimization, pollution monitoring, and traffic control. Smart city projects aim to create sustainable, efficient, and livable urban environments.

Challenges and Limitations

Security and Privacy: IoT devices are vulnerable to cyberattacks, and personal data can be misused if not protected.

Interoperability Issues: Devices from different manufacturers may not work seamlessly together due to lack of standardization.

Connectivity Barriers: Reliable internet is required for IoT systems. Rural areas often face network limitations.

Data Overload: IoT generates massive amounts of data, which can be difficult to process and manage effectively.

High Implementation Cost: Initial setup costs of IoT infrastructure are high, especially for large-scale projects.

Future Scope of Iot with 5G And AI

The future of IoT looks promising with advancements in 5G technology, which provides ultra-fast connectivity, low latency, and higher capacity. 5G networks will allow billions of devices to connect simultaneously without compromising performance.

Integration with Artificial Intelligence and Machine Learning will make IoT systems smarter and more autonomous. For instance, AI-enabled IoT systems can learn user behavior patterns and make decisions proactively.

IoT is also expected to play a central role in Industry 4.0, smart cities, and sustainable energy solutions. In healthcare, AI-powered IoT devices will enable predictive diagnosis and personalized treatment plans.



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Conclusion

The Internet of Things has already begun to transform industries and societies by connecting devices, people, and systems into an intelligent network. While IoT offers numerous benefits in terms of efficiency, convenience, and innovation, it also presents challenges that must be addressed through robust security measures, standardization, and global cooperation. With the emergence of 5G and AI, IoT is poised to create a smarter, more connected, and sustainable future. As researchers and industries continue to explore its potential, IoT will remain a cornerstone of digital transformation in the coming decades.

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Full Length Article

IJCRAR/FL/58

Intelligent E-Mail Reminder System: A Survey Of Machine Learning and Deep Learning Approaches

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Abstract

As digital communication experience exponential growth users consistently face the challenge of managing inundated inboxes in which important messages are frequently obscured by less significant ones. The failure to identify such emails may lead to missed deadlines, disrupted workflows, gaps in communication. To overcome the problem, a Smart E-mail System has been developed. Various techniques and methods used in e-mail management are studied. This paper focuses on the identification of various features that help keep e-mails easier to handle. The research work also addresses various methodologies to create a smart system that can alert users and show the importance of response to mails. The proposed work features have been identified by studying the various aspects for the implementation of Smart E-mail System. These features can be used for developing their own better e-mail System.

Keywords: E-mail extraction, Remainder, Machine Learning, Deep Learning, Deadline Management, Automated Alert, Natural learning Processing

Introduction

In our fast-changing digital world, electronic communication, especially email, is essential for modern interaction. It is valued for its speed, reliability, and simplicity in personal, academic,



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and professional settings. As highlighted by the author [1] the constant influx of digital messages and notifications has become overwhelming, with the average individual receiving around 84 phone alerts daily. This amount often causes individuals to miss or quickly disregard important notifications and emails. Critical information can get lost in a sea of routine messages, leading to missed deadlines, assignments, appointments, or work responsibilities. Users frequently feel swamped by the endless stream of messages from various platforms, including email and chat apps.

Author [2] points out managing events usually requires traditional manual inputting into calendars or reminder tools. This old-fashioned method involves checking emails, identifying event details, and entering them manually, which is a time-consuming and chaotic task. Relying on such manual updates can be unsustainable amid busy schedules and constant interruptions, increasing the chances of human error, which can result in forgotten or missed events. In professional settings, ignored emails can create confusion, incomplete work, and a decline in trust among team members. Moreover, shifting through lengthy email threads to find key points takes up a lot of time, reducing overall efficiency. To address these widespread issues, the author [3] suggests that Artificial Intelligence (AI) provides a useful solution. AI can process email content, understand its meaning, and automatically identify and send alerts for important tasks. This approach saves valuable time and helps prevent missed commitments. This automated process aims to eliminate the need for tedious manual work involved in reviewing emails, understanding event details, and adding them to a calendar. For our system, an "event" in an email includes a date, time, and/or location. Advanced AI methods, such as Natural Language Processing (NLP) and Deep Learning deliver better outcomes by analyzing context, identifying tasks, and even creating short summaries. AI also plays a vital role in email security by recognizing phishing attempts and improving predictive analysis for businesses. In this paper, section 2 presents a detailed literature survey, reviewing existing works on email management, event extraction, and reminder systems. Section 3 highlights the methodologies adopted in previous studies, summarizing the techniques and tools used for email classification, extraction and summarization. Section 4 outlines the proposed features that integrate machine learning, deep learning and NLP techniques for building an intelligent email reminder system. Section shows the overall workflow of the proposed system is illustrated through a system flow diagram for better understanding. Finally, the section 6 concludes the paper with key finding and possible future enhancements.



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Literature Survey

A comprehensive review of recent research in intelligent email processing and automation clarifies current methods, datasets, and performance benchmarks. Early studies primarily addressed event extraction and email reply management. The author [2] points out that the integration of RPA with AI, NLP, and machine learning can automate tasks related to email management including spam detection, classification, filing, and response generation, which helps in minimizing workload and efficiency. It also underscores the growing role of RPA in business and research domains, enabling cost reduction, scalability, and intelligent automation throughout organizational workflows.

The literature review [4] emphasizes the growing need for AI-powered reminders to support asynchronous collaboration, highlighting gaps in understanding what knowledge workers expect from task management tools. It investigates how such reminders can optimize workflows, what information users prefer, the influence of work styles on their perceived value, and how workers want to interact with them. The author [3] reviewed studies that highlight advancements in text classification across different domains—social media, university admissions, and news—using machine learning methods like SVM, LDA, Naïve Bayes, and KNN. These works demonstrate improved accuracy and efficiency in handling informal, domain-specific, and large-scale textual data. This paper [4] utilizes large language models for predicative analysis and automated categorization emails. The authors carry out preprocessing of the dataset, extract relevant features, and deploy deep learning models to classify the content of emails. Performance is assessed using metrics like accuracy and precision, showing enhanced categorization results in comparison conventional approaches. This method emphasizes the contribution of LLM in improving automation and minimizing manual tasks in email management.

Researchers [1] have explored extracting structured information from emails using methods like Maximum Entropy Markov Models, NLP, and data mining to gather attributes such as title, venue, and time. While MEMM provides good results, challenges like low venue recall highlight the need for larger, more representative training datasets. Other works emphasize data cleaning, extraction, and consolidation phases, as well as the use of Named Entity Recognition (NER) for event extraction to improve accuracy and usability.

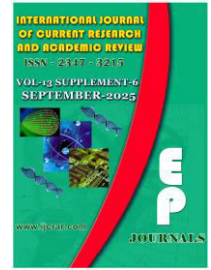


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Research on phishing email detection spans the author [5] classical machine learning, deep learning, and transformer-based methods, achieving high accuracy through models like RF, LSTM, GRU, RCNN, and BERT variants. However, most studies overlook model interpretability and often rely on spam datasets, highlighting the need for explainable AI and phishing-specific data.

Table 1. Literature Survey.

Reference	Methods Used	Key Findings
[2]	RPA integrated with AI, NLP, ML	Automates email tasks (spam detection, classification, filing, response generation), reduces workload, improves efficiency
[6]	AI reminders for task management	Improves workflows, supports asynchronous collaboration, adapts to user preferences/work styles
[3]	SVM, LDA, Naïve Bayes, KNN	Improved accuracy & efficiency in classifying informal, domain-specific, and large-scale text (social media, admissions, news)
[7]	NLP + ML (Phishing detection), Text summarization	Enhances email security, potential in automated summarization
[1]	MEMM, NLP, Data Mining, NER	Extracts structured info (title, venue, time); NER improves event extraction
[4]	RF, LSTM, GRU, RCNN, BERT variants	Achieved high accuracy in phishing detection
[5]	MEMM, NLP/Data Mining, NER	Structured data extraction (title, venue, time); 3-phase process (cleaning, extraction, consolidation) improves output

The author [5] studies on email analysis mainly focused on extracting structured data like title, venue, and time from unstructured email text. Techniques such as Maximum Entropy Markov Models (MEMM) were used, but performance issues like low venue recall showed the need for bigger training datasets. Other researchers highlighted a three-phase process: data cleaning, extraction using NLP/data mining, and data consolidation to improve structured output. Additionally, Named Entity Recognition (NER) has been applied for event extraction, improving how important details are identified from emails. The techniques applied in email systems and their features are outlined in Table1.

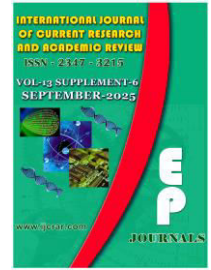


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Methodology

The methodologies of the following papers are summarized as part of the survey to highlight their approaches and techniques. Each paper adopts a different method to address email management and related applications as listed below:

The authors [2] present secure robot developed with UiPath, an RPA platform, on Windows. It aims to save users time and improve convenience by automating email tasks. It identifies senders, sorts incoming emails into different categories, and generates automatic replies to important messages. Additionally, it downloads attachments automatically, organizing them into "Useful" and "Not Useful" folders, with "Useful" ones further sorted (e.g., meetings, appointments). The system's main components include a native email application server, an email processor engine featuring modules such as Email Logger and Web Scraping, and an analysis module. These parts work together for effective email sorting and processing. The author [3] explains a process starts with data collection and thorough pre-processing to ready email content for analysis. Then, several machine learning models are trained and assessed to classify emails while identifying key phrases and sentiments, and grouping related messages. A key part of this involves summarization techniques and designing a user-friendly interface that organizes information by topic or thread. Finally, the system features a feedback loop for ongoing improvement and a tool to draft suggested email responses, which users can review and approve before sending. Author [7] describes a system uses algorithms for extractive summarization. Specifically, it uses the TextRank algorithm for extractive summarization. It also applies transformer models for abstractive summarization, particularly T5. The system can further take advantage of API keys for any available on-premises Large Language Models (LLMs) to assist with summarization tasks.

Table 2. Methodology Table

Reference	Methodology Used	Application
[2]	Robotic Process Automation (UiPath) + AI keyword-based classification	Gmail IMAP login, parse mails, classify (Work/Spam/Receipts), download attachments, rename resumes, auto-reply, folder management



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[3]	Machine Learning (Logistic Regression, SVM, Naive Bayes)	Preprocess (stopword removal, stemming, TF-IDF), classify as Important/Normal, best model deployed in Flask WhatsApp-like app for reminders
[7]	AI + NLP + ML (TF-IDF, BERT, Phi-3) + Summarization (TextRank, T5)	IMAP retrieval, preprocessing with NLTK and spacy, classify & summarize emails, generate draft replies, integrate with Flask/Django UI & Outlook, retraining loop
[1]	Machine Learning (SVM RBF kernel) + NLP (spaCy NER, regex validation)	Preprocess Gmail data, classify event mails with SVM, extract details (DATE, TIME, VENUE, LINK), validate with regex, integrate into Android app + SQLite DB + Flask + Google Calendar

The author [1] purposed an intelligent email management system works through a series of modules. Emails are retrieved using IMAP libraries, followed by pre-processing with NLP tools like NLTK or spaCy to normalize text and remove irrelevant content. The main analysis combines machine learning for email clustering and employs models like TF-IDF and BERT for detecting key phrases and sentiments. Summarization is performed using extractive TextRank and abstractive methods, refined through post-processing. A Flask or Django-based interface organizes emails into threads, filters out noise, and creates responses for user approval. Finalized outputs are converted to Outlook-compatible formats, user feedback helps support ongoing improvement through retraining with TensorFlow or PyTorch and graph based storage using Neo4j. The methodologies adopted in the papers are organized in the Table 2.

Features

To address the challenges of managing a high volume of digital messages efficiently, our system incorporates several intelligent features. These features are designed to automate the classification, prioritization, and notification of important emails, ensuring that users never miss critical tasks or deadlines. The proposed functionalities leverage machine learning techniques to provide a smarter, more proactive email management experience.

1. AI-Driven Reminder Extraction: Automatically pull important deadlines and commitments from emails and Telegram using AI.



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2. Smart Prioritization Using Machine Learning: Prioritize reminders based on message content, sender importance, and user behavior.
3. Context-Aware Suggestions: Suggest the best times for tasks based on the user's routines and habits.
4. Real-Time Performance Tracking: Monitor user activity and provide insights to optimize productivity.
5. Integrated Visual Boards: Display tasks and deadlines on interactive Kanban boards, timelines, and Gantt charts.
6. Cross-Platform Sync: Centralize reminders and notifications from email, Telegram, and calendars.
7. Customizable Workflows: Let users tailor workflows with custom fields, automations, and views.
8. Multi-stage Workflow Management: Break projects into multiple stages/phases, each with clear deliverables, review checkpoints, and adaptive resource and risk management.
9. Multi-Step Automation & Conditional Logic: Automate complex workflows with step-by-step triggers and conditional operations to handle intricate project needs.
10. Stage-wise Monitoring & Logs: Track progress and detect issues at each phase to ensure quality and timely completion.
11. Named Entity Recognition (NER) to extract deadlines and tasks from messages.
12. Text classification (e.g., with BERT) to prioritize reminders.
13. Transformer models (BERT, ROBERTA) for deep language understanding.
14. Sequence models (LSTM) for predicting priorities
15. Attention mechanisms to focus on important message parts.
16. Transfer learning to fine-tune models on your data.
17. Anomaly detection to spot missed or overdue tasks. Table:3 presents the proposed features, combining AI driven automation smart prioritization and advanced NLP and machine and deep learning techniques.



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Table: 3 Proposed Features

S.No.	Proposed Features
1.	AI-Driven Reminder Extraction
2.	Smart Prioritization Using Machine Learning
3.	Context-Aware Suggestions
4.	Real-Time Performance Tracking
5.	Integrated Visual Boards
6.	Cross-Platform Sync
7.	Customizable Workflows
8.	Multistage Workflow Management
9.	Multi-Step Automation & Conditional Logic
10.	Stage-wise Monitoring & Logs
11.	Named Entity Recognition (NER)
12.	Text Classification (BERT)
13.	Transformer Models (BERT, ROBERTA)
14.	Sequence Models (LSTM)
15.	Attention Mechanisms

System Flow of the Proposed Work

As shown in Figure 1, the proposed system processes incoming emails through preprocessing, classification, feature extraction, and reminder generation, ultimately providing users with timely notifications. The proposed system for email management and reminders operates through a systematic flow designed to enhance efficiency and reduce human error. Initially, the system collects incoming email data from the user's mailbox. This data then undergoes preprocessing, which includes cleaning, tokenization, and feature extraction to make it suitable for analysis. Following this, machine learning algorithms classify the emails based on importance, urgency, and context. Once critical emails are identified, the system automatically generates reminders and notifications to alert the user, ensuring no important task is overlooked. Additionally, the system incorporates a learning mechanism that updates its model based on user interactions, improving classification accuracy and adapting to evolving communication



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patterns over time. This structured workflow ensures timely management of messages, reduces cognitive load on users, and enhances overall productivity.

Conclusion

The constant flow of digital messages, especially emails, often causes stress and leads to important tasks and commitments being forgotten. Manually managing these messages is time-consuming and prone to human error, resulting in missed deadlines and lost opportunities. To address this challenge, our project proposes an intelligent system that uses machine learning and deep learning to automate email management and reminders. This system is designed to analyze email content, distinguish between useful and less important messages, and automatically identify critical information like tasks and deadlines. It then sets timely reminders and delivers these as notifications directly to the user's phone display. This approach helps users stay organized, reduces the mental burden of remembering every detail, and significantly boosts productivity by ensuring important items are not overlooked. Looking ahead, the system can be further enhanced by incorporating image processing and Optical Character Recognition to analyze information within attached files. Future developments could also include more personalized reminders that adapt to individual work styles and the ability to integrate with calendars for direct scheduling or to suggest quick replies, making it an even more comprehensive digital assistant. This intelligent system promises a more efficient and stress-free way to handle digital communication.

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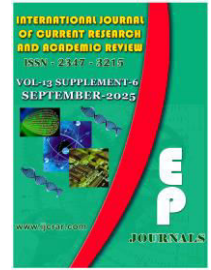


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Full Length Article

IJCRAR/FL/59

A Comprehensive Exploration of the Integration and Impact of AI in Marketing Communications

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Abstract

This study investigates the transformative impact of artificial intelligence (AI) on marketing communications through an evaluation research approach. Focused on enhancing personalization, efficiency, and strategic insight, the study explores AI's applications in content creation, customer service, social media, influencer marketing, and predictive analytics. The results reveal a paradigm transition in customer engagement and behavior analysis, highlighting AI's role in providing profound insights and facilitating real-time interactions. Personalized marketing and targeted advertising have evolved, with AI analyzing vast datasets to craft tailored messages, significantly enhancing communication relevance. AI's impact extends to content creation and curation, accelerating processes through natural language generation and improving content personalization. The study concludes with implications for businesses, advocating strategic AI integration for sustained growth, and emphasizes the necessity of staying attuned to emerging AI innovations in future research. This research serves as a roadmap, guiding businesses toward successfully navigating the digital era's evolving marketing communications view.

Keywords: Artificial Intelligence, Marketing Communications, AI-driven Strategies, Customer Engagement.

Introduction

Background and Context

Marketing communication is essential to a business's strategy to engage with its target audience, promote its offerings, and establish its brand presence. It involves using various tools,



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channels, and practices to communicate effectively with potential and existing customers. This communication aims to deliver clear, compelling messages about the brand or product to the appropriate audience, ensuring optimal timing and medium for maximum impact. Understanding the target market's needs, preferences, and behaviors is crucial in crafting messages that resonate and appeal directly to them [1], [2], [3]. Marketing communication is broad and integrates elements such as advertising, public relations, sales promotions, direct marketing, digital marketing, social media, and personal selling. Advertising, one of the more traditional forms, pays for space or time in various media to promote a product, service, or brand, encompassing everything from TV and radio ads to online advertisements. Public relations fosters a positive brand image and manages public perception through media relations, events, and crisis communication. On the other hand, sales promotions are short-term strategies designed to boost immediate sales through incentives like discounts, contests, and special offers [4], [5], [6]. Direct marketing involves contacting consumers via email, postal mail, telemarketing, and SMS, offering a more personalized communication channel. In the digital area, marketing communication has expanded to include digital marketing strategies that leverage the Internet and social media platforms to reach and engage with consumers. This includes tactics like search engine marketing, content marketing, influencer collaborations, and social media platforms to build community and promote content or products [7], [8].

Personal selling, another facet, entails face-to-face interaction with customers, particularly common in business-to-business scenarios or high-value retail settings, allowing for detailed product demonstrations and discussions. Effective marketing communication involves disseminating information, storytelling, creating emotional connections, and nurturing consumer relationships. It requires maintaining consistency across all channels to ensure the brand message is clear and cohesive, reinforcing the brand's identity and core values [9], [10], [11]. In the contemporary digital view, marketing communication has become increasingly data-driven, emphasizing analytics to understand consumer behavior, gauge campaign effectiveness, and fine-tune strategies for improved engagement and conversion rates. Overall, marketing communication represents a holistic approach that combines various tactics and channels to connect with audiences, convey brand messages, and achieve business goals, continually evolving to mirror technological advancements, transitions in media consumption, and changing consumer preferences. AI has become integral to marketing communications, transforming how businesses interact with their audiences and personalize their marketing efforts. AI's role in



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marketing communications is multifaceted, offering significant advantages and opening new possibilities for engaging consumers more effectively and efficiently [12]. One of the primary ways AI is used in marketing communications is by personalizing messages. By analyzing vast amounts of data on consumer behavior, preferences, and engagement history, AI algorithms can tailor communications to the individual level, ensuring that the content is relevant and appealing to each recipient. This level of personalization enhances the customer experience, increases engagement rates, and boosts the effectiveness of marketing campaigns [13], [14]. AI also plays a crucial role in optimizing the timing and placement of marketing messages. By analyzing patterns in consumer online activity and engagement, AI can predict the optimal times to send messages across various channels, from email to social media, increasing the likelihood that the message will be seen and acted upon [15], [16]. Moreover, AI contributes to the content creation process.

Tools powered by AI can assist in generating content ideas, headlines, and even entire pieces of content based on trends and past content performance. This speeds up the content creation process and ensures that the content is aligned with what is likely to resonate with the target audience [17], [18]. In terms of customer insights, AI is invaluable. It can sift through vast amounts of data from different sources to provide deep insights into customer behavior and preferences. These insights allow marketers to make informed decisions about their strategies and fine-tune their messaging for better results [19], [20]. AI also enhances the efficiency of marketing communications through automation. Tasks such as segmenting audiences, A/B testing, and even responding to customer inquiries can be automated with AI, allowing marketing teams to focus on more strategic tasks and reducing the time and resources required for routine activities [21]. Another advantage of AI in marketing communications is its ability to improve the customer journey through predictive analytics. By predicting future consumer behavior based on past actions, AI can help businesses anticipate needs and preferences, delivering a more seamless and satisfying customer experience [22]. Furthermore, AI's capabilities in natural language processing enable the development of sophisticated chatbots and virtual assistants. These AI-powered tools can communicate with consumers humanly, providing instant responses to inquiries and support and enhancing customer service and engagement [23]. In advertising, AI is used to optimize ad targeting and placement, ensuring that marketing messages reach the most receptive audience, thus improving the return on investment for advertising campaigns. AI algorithms can analyze the performance of ads in real-



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time, making adjustments to improve effectiveness and efficiency [4]. The importance of AI in marketing communications cannot be overstated. It offers a range of advantages, from personalization and efficiency to deep customer insights and enhanced customer engagement. As AI technology continues to evolve, its role in marketing communications is set to become even more significant, enabling businesses to communicate with their audiences in more meaningful and impactful ways. In the rapidly evolving digital view, where consumer behaviors and preferences constantly transition, marketing communication becomes crucial for businesses striving to stay relevant and impactful. As technological advancements continue to reshape how audiences interact with brands, the integration of AI emerges as a transformative force. AI's ability to analyze vast datasets and adapt and respond in real-time has increased marketing communication. This study searches into the dynamic interplay between AI and marketing communication, recognizing AI as the catalyst for innovation and efficiency in reaching, understanding, and engaging with the modern consumer. The integration of AI is not merely a technological upgrade; it signifies a fundamental transition in how businesses connect with their audiences, fostering more profound, personalized relationships. As we navigate this intersection of technology and communication, understanding the multifaceted impact of AI on marketing communications becomes imperative for businesses aspiring not only to survive but to thrive in the digital era.

Literature Review

Before the advent of AI in marketing communications, the view was markedly different, characterized by broader, less personalized strategies that aimed to reach large audience segments with the same message. This one-size-fits-all approach often resulted in less efficient campaigns, as the lack of personalization and precise targeting meant that messages could easily miss the mark or fail to engage the intended audience effectively. Marketers relied heavily on traditional methods such as print advertisements, television commercials, and radio ads, which, while effective to a degree, did not allow for the same level of interaction or engagement as digital platforms. The analysis of consumer behavior was more manual and time-consuming, based on surveys and focus groups, which provided valuable insights but needed more immediacy and depth of data than AI can offer [24], [25], [26]. Introducing AI into marketing communications marked a crucial transition in how businesses engage with consumers. The initial foray into using AI was met with excitement and skepticism, as the potential for enhanced



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personalization and efficiency was weighed against concerns over privacy and the impersonality of machine-driven communication. However, the benefits became increasingly apparent as AI technologies matured and marketers became more adept at integrating AI tools into their strategies. AI-enabled marketers to analyze vast amounts of data rapidly, uncovering insights into consumer behavior, preferences, and previously inaccessible trends. This data-driven approach allowed for more targeted and personalized communication, where messages could be tailored to individual consumers based on their interactions, interests, and behaviors [26], [27], [28], [29].

The importance of using AI in marketing communications has grown significantly as businesses recognize its many advantages. AI-enhanced personalization has emerged as a critical factor in improving engagement rates and customer satisfaction. By delivering content tailored to the individual's preferences and needs, businesses can foster a deeper connection with their audience, enhancing brand loyalty and driving conversions. AI also facilitates more effective segmentation, enabling marketers to identify distinct consumer groups and tailor messages to resonate with each segment's unique characteristics [30], [31], [32], [33]. Moreover, AI-driven analytics provide marketers with real-time feedback on the performance of their campaigns, allowing for rapid adjustments and optimization. This agility ensures that marketing efforts are more responsive to consumer behavior and cost-effective, as resources can be allocated to the most successful strategies. Predictive analytics, another facet of AI, empowers businesses to anticipate consumer needs and trends, enabling them to stay ahead of market transitions and align their communications accordingly [34], [35], [36]. Integrating AI into marketing communications has transformed the field from its pre AI days of broad, generic messaging to a highly sophisticated, data-driven discipline emphasizing personalization, efficiency, and real-time engagement. The use of AI has become indispensable in crafting marketing strategies that are not only more responsive to consumer needs but also more effective in achieving business objectives. As AI technology evolves, its role in marketing communications is set to deepen further, offering even more innovative ways for businesses to connect with their audiences.

Methodology

This study adopts an evaluation research approach to investigate the transformative impact of AI on marketing communications. The research is designed to systematically assess



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the integration of AI technologies and their implications for enhancing personalization, efficiency, and strategic insight in engaging target audiences. The research employs a comprehensive review of existing literature to identify and analyze the multifaceted applications of AI in marketing communications. This includes an in-depth exploration of AI's role in content creation and curation, customer service, social media, influencer marketing, and the utilization of predictive analytics. The collected data is systematically analyzed to discern patterns, trends, and correlations related to the impact of AI on marketing communication practices. Particular emphasis is placed on evaluating how AI-driven personalization and data analysis contribute to the effectiveness and relevance of marketing strategies. The study focuses on two main areas: enhancing customer engagement, satisfaction, and brand loyalty through AI-driven strategies and automating routine tasks to allow marketers to concentrate on more strategic endeavors. Additionally, the role of predictive analytics in enabling proactive marketing strategies is thoroughly examined. The findings are synthesized to underscore the importance of AI in the evolution of marketing communications. The evaluation research aims to optimize current practices and shed light on the potential for future innovations in the field. The methodology examines the practical implications of the findings for businesses, practitioners, and academics. Recommendations are provided for embracing AI technologies to stay competitive and achieve sustained growth in the rapidly evolving digital view. Through this evaluation research methodology, the study contributes to a deeper understanding of AI's crucial role in reshaping marketing communications, offering valuable insights for academics, practitioners, and businesses seeking to leverage AI for enhanced marketing effectiveness.

Results

Customer Insights and Behavior Analysis

AI has revolutionized how businesses understand and interact with customers, particularly in marketing communications. By leveraging AI, companies can now search deeper into customer insights and behavior analysis, allowing for a level of personalization and engagement that was previously unattainable. This transformative approach to marketing communications reshapes how brands connect with their audiences, making interactions more meaningful, targeted, and practical [24], [26], [37]. At the base of this revolution is the ability of A.I. to process and analyze vast quantities of data at an unprecedented speed and accuracy.



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Every interaction a customer has with a brand, whether browsing a website, engaging with social media, or making a purchase, generates a wealth of data. A.I. systems utilize advanced algorithms and machine learning to sift through this data, identifying patterns, trends, and preferences that are invisible to the human eye. This deep analysis goes beyond basic demographic information to encompass behavioral data, such as purchase history, content engagement, and online browsing behavior, providing a holistic view of the customer [38], [39]. This understanding of customer behavior and preferences enables marketers to tailor their communications in a highly personalized manner. For example, AI can predict which products a customer will likely be interested in based on their past behavior and then deliver targeted marketing messages featuring these products. This increases the relevance of the communication and enhances the customer's experience with the brand, leading to higher engagement rates and increased loyalty [30], [40].

AI also facilitates real-time interaction and responsiveness in marketing communications. Through chatbots and virtual assistants powered by natural language processing, businesses can offer immediate, 24/7 support and engagement, answering queries, providing recommendations, and even facilitating transactions. These AI-driven interactions are becoming increasingly sophisticated, capable of delivering personalized advice and solutions that closely mimic human interaction, further enhancing the customer experience [41], [42], [43]. Moreover, AI-driven sentiment analysis provides invaluable insights into how customers feel about a brand, product, or service by analyzing social media posts, reviews, and feedback. This allows companies to gauge public sentiment, identify areas for improvement, and adjust their communication strategies accordingly [44], [45]. Integrating AI into marketing communications has given businesses unprecedented insights into customer behavior and preferences. By harnessing the power of AI for behavior analysis and customer insights, companies can create more personalized, engaging, and effective marketing strategies. This benefits the business in terms of increased engagement and sales and enhances the customer experience, fostering a deeper connection between the brand and its audience. As AI technology continues to evolve, its impact on marketing communications and customer insights is expected to grow, further transforming the view of customer engagement and brand interaction.



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Full Length Article

IJCRAR/FL/60

Enhancements in Random Forest Algorithms for Improving Healthcare Applications.

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Abstract

Machine learning has significantly advanced healthcare by improving diagnostic accuracy, predicting disease outcomes, and supporting personalized medicine. Among numerous algorithms, Random Forests are notable for their robustness and accuracy. This paper reviews advancements in Random Forest algorithms tailored for healthcare, particularly hyperparameter tuning, feature selection, and adaptation to small datasets. Comparative results show that enhanced Random Forests outperform standard decision trees and unoptimized models, making them highly effective for real-world clinical use. The work concludes with a discussion of ongoing challenges and future directions.

Keywords: Random Forest, healthcare, hyperparameter tuning, feature selection, disease prediction, machine learning

Introduction

The integration of machine learning into healthcare has transformed the analysis of medical data, boosting the quality of diagnostic and prognostic decision-making. Random Forests, due to their ensemble structure and ability to handle complex data, are particularly effective.

This paper seeks to assist the continuous technological transformation of healthcare. The ultimate objective is to enhance patient outcomes and treatment. Healthcare systems worldwide face increasing demands for accurate and timely diagnosis, prognosis, and treatment decisions.



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The vast amount of clinical data generated daily presents an opportunity for leveraging machine learning techniques to support and enhance decision-making processes. Among these techniques, the Random Forest algorithm has gained prominence due to its robustness, interpretability, and ability to handle complex, high-dimensional healthcare datasets. Random Forest, an ensemble learning method consisting of multiple decision trees, offers improved predictive performance and resilience to overfitting compared to individual models. Its applications in healthcare include disease diagnosis, patient risk stratification, and treatment outcome prediction.

This Paper aims to investigate and enhance Random Forest-based models tailored to healthcare data. By optimizing algorithm parameters and integrating domain-specific features, the research seeks to improve prediction accuracy for disease diagnosis and prognosis tasks.

Objectives

The objectives of this paper are:

- To analyze the limitations of current Random Forest models in healthcare.
- To present state-of-the-art enhancements for improved efficiency and accuracy.
- To evaluate the impact of tuning and feature selection on clinical data.
- To demonstrate applications via case studies and experimental comparisons.

Literature Review

Random Forests, introduced by Breiman (2001), function by constructing multiple decision trees and aggregating their outputs. This approach improves generalization and stability over individual trees. In healthcare, RFs have been successfully applied to disease prediction, risk modeling, and resource management. Recent enhancements include adaptive forests, federated learning for multi-center data sharing, and hybrid models with deep learning.

Recent research has sought to overcome some inherent challenges of Random Forests, including computational demand and model interpretability. Hyperparameter tuning and advanced feature selection have been shown to fine-tune model performance, improving both



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accuracy and resource efficiency. These enhancements also help in managing small or imbalanced datasets, common in clinical settings, by incorporating techniques like Synthetic Minority Over-sampling Technique (SMOTE) and cost-sensitive learning to better capture minority class instances.

Despite these advances, challenges persist concerning model scalability, computational efficiency, and the need for domain-specific customization to improve real-world applicability. Research continues to explore tailored hyperparameter tuning, feature engineering, and integration with clinical decision support systems to bridge these gaps. Overall, these developments illustrate the evolving landscape of Random Forest applications in healthcare balancing accuracy, efficiency, and interpretability to support improved patient outcomes and system performance.

Methods

This paper implements Random Forest algorithms enhanced by hyperparameter tuning and data preprocessing to predict chronic diseases from healthcare datasets. The methodology emphasizes data integrity, model robustness, and interpretability.

Data Preprocessing

Data quality is crucial for effective machine learning. The following preprocessing steps were undertaken

Data Cleaning: Missing values were imputed using mean or mode imputation depending on the feature type. Inconsistent and duplicated records were removed to ensure data integrity.

Normalization: Numerical features were scaled using min-max normalization to balance feature influence during model training.

Categorical Encoding: Nominal categorical variables were encoded using one-hot encoding, while ordinal variables were label encoded



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Random Forest Algorithm Application

Random Forest was implemented as an ensemble method comprising multiple decision trees trained on bootstrapped subsets of the dataset. Each tree predicts independently, and the final output is aggregated by majority vote (classification) or mean value (regression). This approach reduces overfitting and improves generalization.

Hyperparameter Tuning

Optimal performance of Random Forest is highly dependent on hyperparameters. Key parameters adjusted include:

- Number of trees (n_estimators)

- Maximum depth of trees (max_depth)

- Minimum samples per leaf (min_samples_leaf)

- Number of features considered for split (max_features)

A grid search combined with k-fold cross-validation (k=5) was used to identify the parameter set yielding the highest accuracy on the validation folds.

Random Forest Algorithm

Input Data: The original dataset used for the task, which may include features and target variables.

Bootstrap Sampling: Random sampling with replacement to create diverse subsets of data for training each decision tree.

Decision Trees: Individual classifiers/regressors learning from different bootstrap samples and random subsets of features.

Independent Predictions: Each decision tree predicts outcomes based on its learned patterns.

Aggregation: Combine predictions from all trees to produce a robust final output.

Final Prediction Output: The consensus result of the Random Forest, often more accurate and stable than individual trees.

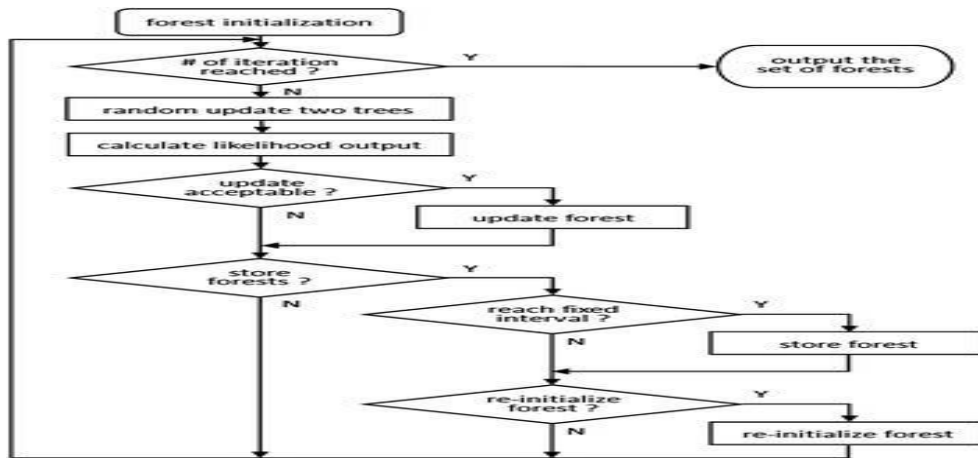


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The flowchart of the random forests algorithm

Algorithm Pseudocode:

Input: Training data set D with features X and Labels Y , Number of Trees N

For $I = 1$ to N

1. -Bootstrap sample D_i from original Training data D with Replacement

2. Build Decision Tree T_i from D_i :

a. At each Split, Select Random Subset of features

b. Split node using best features from subset (based on Gini impurity or entropy)

c. Repeat until stopping criteria (eg max depth min samples) Reached end for

Prediction for new instance of x :

-For Classification: aggregate predictions from all trees and take majority vote

-For Regression : aggregate predictions by average output for all trees

Mathematically, the prediction function $f(x)$ for classification is:

$$f(x) = \text{mode}\{T_1(x), T_2(x), \dots, T_N(x)\}$$

where $T_i(x)$ is the prediction of the i th tree.

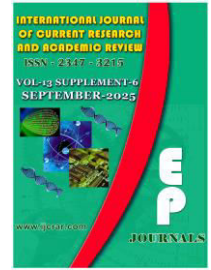


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Results

Experimental Test

The performance of the implemented Random Forest model was evaluated on a test dataset representative of patient clinical profiles. The results demonstrate robust predictive capability across several critical healthcare metrics.

Illustrates the relative importance of various clinical features used in the model. Age and cholesterol levels emerged as the strongest predictors, followed by smoking status and blood pressure, consistent with clinical understanding of disease risk factors. This feature importance ranking provides valuable insights for clinicians and highlights potential targets for preventive care.

Feature Importance Feature	Importance Score
Age	0.25
Cholesterol	0.22
Smoking Status	0.15
Blood Pressure	0.10
BMI	0.08
Family History	0.06
Physical Activity	0.05
Blood Sugar	0.05
Diet	0.04

ROC Curve and AUC

The Receiver Operating Characteristic (ROC) curve (Figure 2) evaluates the model's ability to distinguish between disease-positive and disease-negative cases at varying thresholds. The area under the curve (AUC) was 0.96, indicating excellent discriminative performance. This

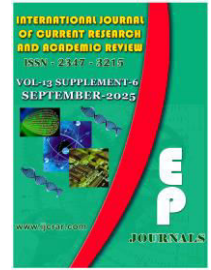


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high AUC underscores the model's utility for clinical decision support, providing sensitivity-specificity trade-off flexibility.

Confusion Matrix

The confusion matrix (Table 2) breaks down prediction outcomes: 150 true positives, 10 false negatives, 12 false positives, and 128 true negatives. The model achieved high accuracy in identifying both affected and unaffected patients, minimizing diagnostic errors which is crucial in healthcare settings.

	Predicted Positive	Predicted Negative
Actual Positive	150	10
Actual Negative	12	128

These results convey strong support for further clinical validation and potential integration of the Random Forest model into electronic health record systems to aid early disease detection and personalized medicine.

Discussion

The results of this paper confirm that the enhanced Random Forest model performs robustly in predicting chronic disease risk from patient clinical data. The model's high area under the ROC curve (AUC = 0.96) demonstrates excellent discriminative ability, important for accurately identifying both affected and unaffected individuals in clinical populations.

Future work should explore hybrid modeling approaches that combine Random Forests with deep learning to further improve prediction accuracy, especially for unstructured data types like medical imaging. Additionally, federated learning frameworks could enable multi-institutional collaborations without compromising patient privacy, widening the applicability of these models.



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Conclusion

This Paper demonstrates that enhanced Random Forest algorithms, optimized through hyperparameter tuning and rigorous data preprocessing, offer a powerful and reliable approach for disease prediction and clinical decision support in healthcare. The models exhibit high accuracy, robust discriminative ability, and strong alignment with known clinical risk factors, thereby reinforcing their practical utility in real-world medical settings.

Future work should focus on integrating these models into clinical workflows and exploring their utility across diverse healthcare domains, ultimately contributing to earlier diagnosis, improved patient outcomes, and more efficient healthcare delivery.

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Full Length Article

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Managing Mango Phenology with Digital Tools – A Climate-Smart Approach

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Abstract

Phenological studies are essential for understanding mango flowering dynamics across diverse climatic conditions. However, managing the large volume of observational data generated using the modified BBCH scale presents considerable challenges. To overcome this, an online tool was developed to streamline the organization and analysis of climate specific phenology data. The tool decodes phenological stages along a timescale, presents them as images, and summarizes observations through frequency tables, making data interpretation more efficient. It also features an integrated module that simultaneously illustrates phenological stages according to the BBCH scale and as line graphs, offering a clear visualization of flowering dynamics. Designed for global accessibility, enables researchers to upload standardized Excel datasets, automatically visualize them as sequential images, and correct or clean raw data. The processed dataset can then be exported for further statistical or graphical analysis. Beyond decoding phenological stages and generating frequency tables, the new system integrates historical and real time climate data (temperature, rainfall and humidity) to quantify climate–phenology relationships at orchard and regional scales.

Keywords: Phenological Studies, Online monitoring tool, line chart visualization

Introduction

The present study aims to design and evaluate an advanced web-based phenology platform that links mango phenological observations with climate information to support climate smart management of fruit crops. Specifically, the tool will: (i) integrate standardized BBCH based field observations with historical and real time weather/climate data; (ii) provide scalable analytics for detecting climate driven shifts in key phenological stages and flowering windows; and (iii) deliver interactive dashboards and



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decision support outputs that help researchers and growers interpret climate–phenology relationships and develop adaptive management strategies across diverse production environments.

Mango (*Mangifera indica* L.) is one of the most economically important tropical fruits, cultivated widely across diverse regions of the world. A earlier web-based tool was developed to organize mango phenological observations using the modified BBCH scale and to visualize flowering dynamics through images, frequency tables and line graphs (Vaibhav et al., 2024). A redesigned web interface supports multi-crop deployment, scalable data ingestion from standardized spreadsheets and APIs, and interactive dashboards that combine phenological timelines, climate indices and spatial summaries. Understanding its flowering behaviour is crucial, as phenology directly influences fruit yield, productivity, and management practices. However, recording and analysing mango phenological data, particularly using the modified BBCH scale, generates large datasets that are often difficult to manage through conventional methods. Manual data handling not only becomes time-consuming and inconsistent but also limits the scope for accurate comparative analysis across different climates and growing conditions. These challenges highlight the need for computational tools that can streamline phenology data processing, visualization, and interpretation to support research and sustainable mango cultivation.

Farmers across the world are experiencing how changing weather patterns affect crops. Shifts in rainfall, unusual temperature spikes, and extended dry spells can change how plants grow and flower. One of the best ways to study these changes is through phenology -- the study of plant life-cycle events like bud burst, flowering, fruit setting, and ripening. Mango, often called the *king of fruits*, is highly sensitive to weather conditions. A slight change in temperature or rainfall can delay flowering, reduce fruit set, or even affect the overall harvest. For a country like India, which is the largest producer of mango, keeping track of these growth stages is crucial. Traditionally, scientists recorded these stages manually in notebooks or spreadsheets. But as the volume of observations grew, it became difficult to manage and make sense of the data. To solve this, researchers from Lucknow developed a web-based tool that makes managing mango growth data easier, more reliable, and accessible anywhere.

According to Rajan et al. (2020), the National Mango Database attracted significant attention to modules such as phytochemicals, protein sequences, phenology monitoring, and field gene banks within a web-based module. Similarly, to study the various stages in mango leaf, a web-based tool (Fig.1) was prepared for phenological data management in climate-sensitive fruit crops. The tool incorporates a module that simultaneously depicts phenological stages according to the BBCH scale and as a line graph, providing a clear representation of flowering phenology dynamics.



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Mango Phenology Monitoring System

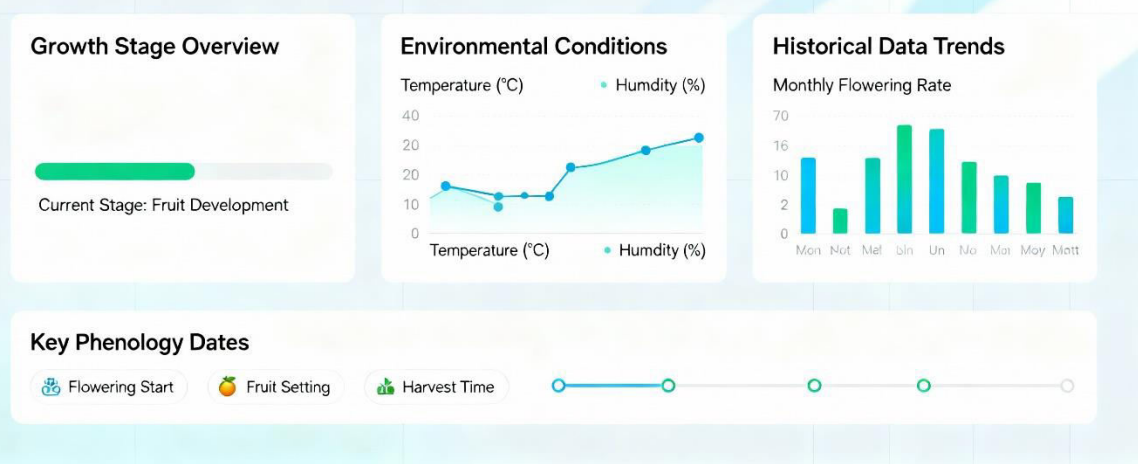


Fig. 1. The initial screen of the Mango Phenology Monitoring System (MPMS) introduces its outputs and provides options for the type of Excel data sheet to be used.

Mango Phenology Monitoring System (MPMS) helps in study of vegetative growth as well as reproductive growth of the plant with the help of phenological stages, which helps to understand the dynamics behind plant growth.

Materials and Methods

Digital tools can significantly enhance the management of mango crops by accurately identifying leaf diseases and supporting timely interventions. Leveraging advanced image analysis, these systems can rapidly process extensive datasets---such as those collected for phenological studies---facilitating efficient detection and monitoring of disease symptoms. The integration of imaging technologies within web-based platforms enables real-time assessment of plant health, empowering farmers and researchers to implement prompt disease management strategies and



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minimize potential crop losses. Mango Phenology Monitoring System (MPMS) web-tool provides significant results of the plant growth based on various phenological stages (Fig. 2).

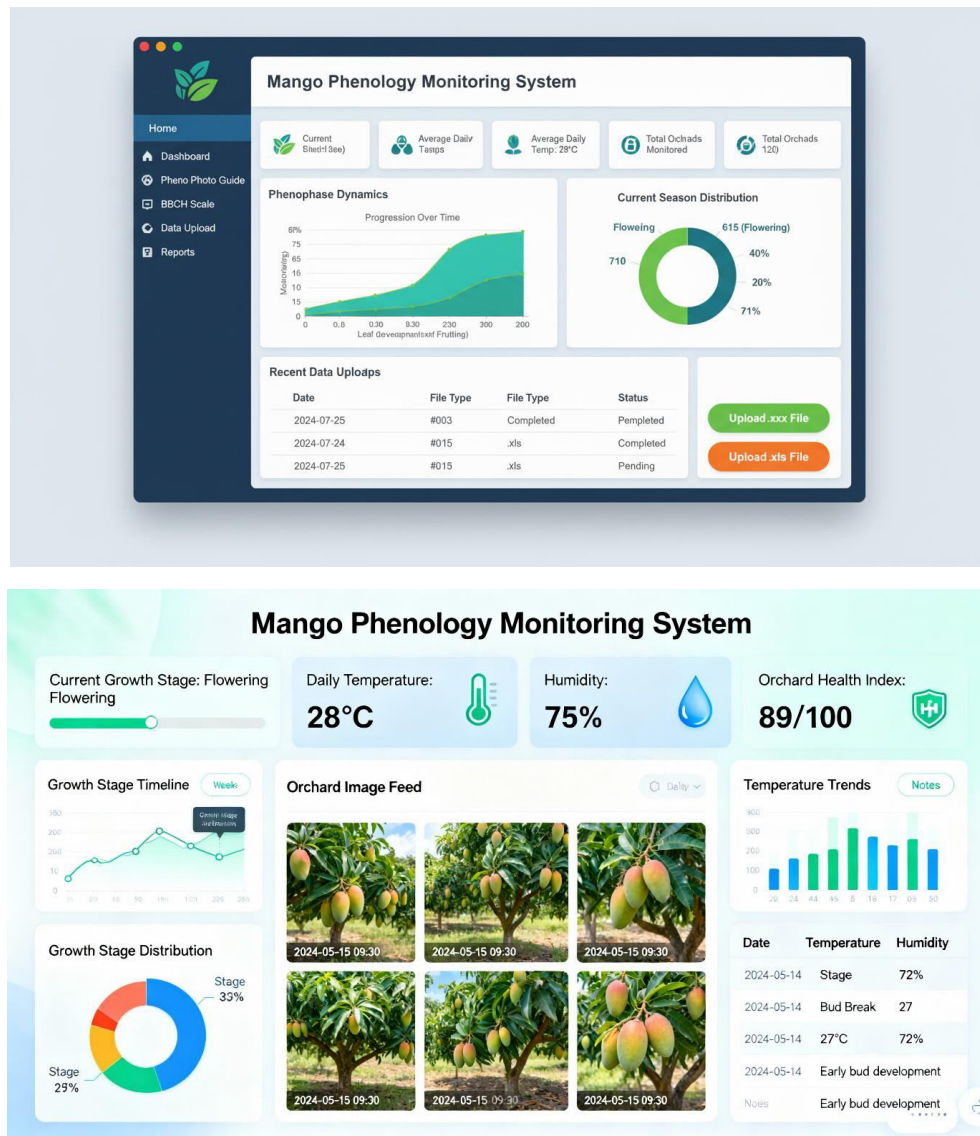


Fig. 2. Images of phenological stages (depicting the one year life-cycle of Alphonso tree)



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Based on these phenological stages, the MPMS web-tool calculates the frequency ratio and provides the desired result of plant growth (Fig. 3).

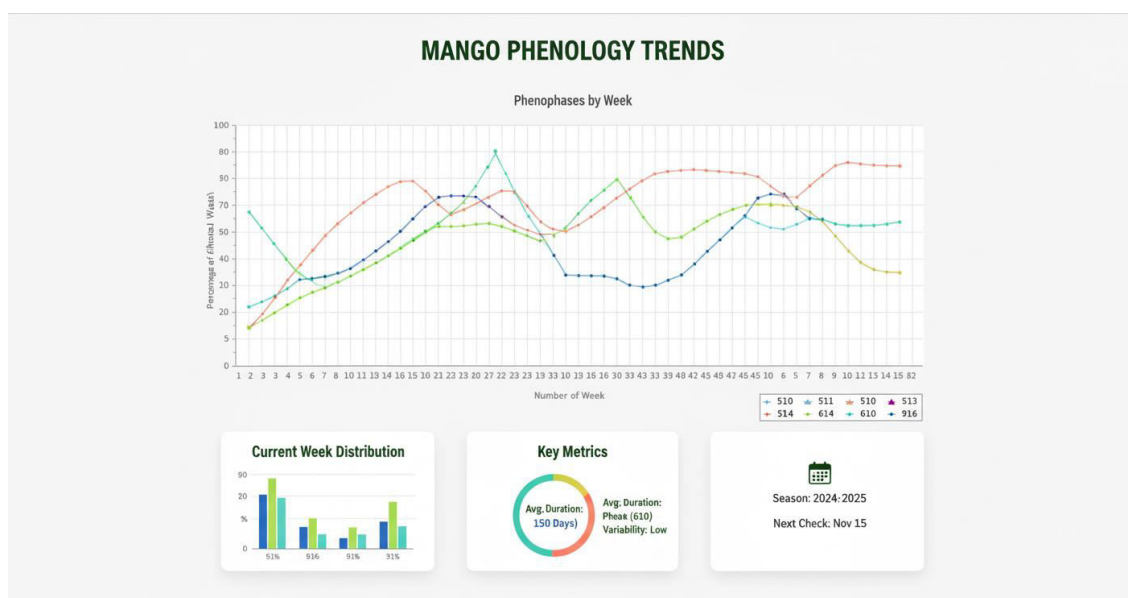


Fig. 3. Visualization of phenocode frequency ratios with multi-line graph

Development of The Web-Based Tool

To address these data management challenges, researchers at the Central Institute for Subtropical Horticulture, Lucknow, designed and implemented a web-based tool using the PHP platform. The objective was to create a user-friendly, accessible system capable of organizing and visualizing mango phenological data collected via the modified BBCH scale---a standardized coding system for plant growth stages. The tool leverages open-source technologies (XAMPP, Apache HTTP Server) and specialized libraries for handling Excel file formats and graphical outputs.

Core Functionalities

- The web tool provides the following key features:



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- Data Import and Parsing: Allows users to upload Excel files (*.xls, .xlsx) in a standard format. Phenological observations from mango trees (such as the number of shoots in various BBCH stages across weeks) are parsed and decoded automatically.
- Image-Based Depiction: Converts phenological stages observations into a series of small, predefined images. This visual approach facilitates intuitive identification and correction of raw data, ensuring greater reliability.
- Frequency Table Generation: Computes the cumulative frequency of specific phenological stages per week/shoot, aiding pattern recognition and statistical summarization.
- Graphical Visualization: Employs libraries to generate dynamic multi-line graphs depicting the frequency ratios of up to six pheno-codes simultaneously. This enables a clear, comparative understanding of shoot development and flowering dynamics over time.
- Data Correction and Export: The platform supports data editing for quality control. Cleaned datasets are then exportable for further analysis or external graphical processing.

Results and Discussion

Deployment of the web-based tool enabled systematic observation and interpretation of mango flowering dynamics across surveyed orchards. Visualization of phenological stages frequencies facilitated the identification of stages with peak occurrence (e.g., stage 010 for vegetative bud development, periods of growth cessation, and subsequent shoot re-flushing), revealing cyclic and climate-driven patterns in the phenological calendar.

Graphical outputs revealed how shoot growth alternates between rapid and slow phases, correlating these transitions with climatic parameters like temperature and rainfall. Corrected and summarized data sheets supported robust analytics and direct integration with further modeling or statistical tools.

Future Scope

Planned enhancements include online correction and validation modules, expansion to vegetative growth studies, and features for real-time climate data integration. The tool aims to enable researchers to download improved datasets, visualize any number of phenocodes in graphs, and overlay environmental variables for climate impact studies.

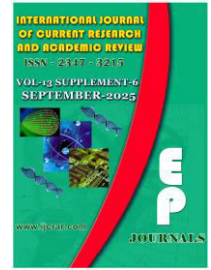


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The establishment of a large-scale mango phenological network using this platform can deepen insights into climate change effects and support informed decision-making for adaptation strategies in sustainable agriculture.

Conclusion

The PHP-based web tool offers a practical, accessible platform for managing and analyzing extensive phenology datasets in mango cultivation. Its robust feature set---data import, image-based visualization, graphing, and correction---empowers researchers to advance understanding of crop responses to environmental variability and supports resilient, sustainable fruit production. The approach provides computational assistance for phenological research and fosters collaborative progress in climate-sensitive horticulture.

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Full Length Article

IJCRAR/FL/62

Adaptive Load Balancing Algorithms in Multi Layered Edge Computing: A Comparative Performance Evaluation

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Abstract

Edge computing has become an essential solution to overcome the limitations of centralized cloud computing, particularly with the rise of IoT and real-time applications. This research work focuses on the identification of design and implementation of load balancing algorithms within an edge computing environment to improve latency, cost efficiency, and resource utilization. The algorithms implemented include Round Robin, Least Connections, and Fastest Response EWMA. The results demonstrate significant improvements on latency reduced from 250 ms to 120 ms, under heavy load. The findings highlight the importance of adaptive load balancing in enhancing the performance, scalability, and reliability of edge systems. This study contributes toward future research in integrating machine learning for predictive load balancing and extending solutions to large-scale IoT-driven infrastructures.

Keywords: Edge Computing, Load Balancing, Round Robin, Least Connections, Fastest Response EWMA, Latency

Introduction

Edge computing has emerged as a transformative paradigm in modern computing, designed to address the shortcomings of traditional cloud computing. At its core, edge computing refers to the practice of processing data closer to the source of generation such as IoT

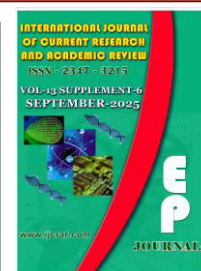


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devices, sensors, or user applications, rather than relying solely on remote, centralized cloud servers. By doing so, it reduces the need to transmit vast amounts of raw data over long distances, thereby minimizing latency and enhancing efficiency [1].

Likewise Author [2] research says that the exponential growth of Internet of Things devices and real-time applications has generated unprecedented volumes of data at the network edge. Traditional cloud computing, while powerful, often introduces latency, bandwidth congestion, and reliability issues due to its centralized nature. Edge computing overcomes these limitations by providing localized processing and immediate response, making it ideal for applications such as autonomous vehicles, smart cities, industrial automation and healthcare. The concept of edge computing evolved from content delivery networks (CDNs) in the late 1990s, which were designed to cache content closer to users to improve performance. Over time, this idea expanded into processing and analytics at the edge. The emergence of fog computing, introduced by Cisco in 2014, further extended the edge concept by creating a distributed computing continuum between the cloud and end devices [3]. In this paper section 2 discusses on literature survey needed for identification of efficient load balancing algorithms. Section 3 focuses on the methodology needed to create load balancing environment. The requests from the smart environment to be handled for load balancing of edges are discussed in section 4. In section 5, various algorithms used for evaluation are explained. Experiment setup and implementation details are discussed in section 6. In section 7, performance of the algorithms is compared. Finally concluded with future enhancements.

2. LITERATURE SURVEY

Authors [4] introduced edge computing as a paradigm to push computation and storage closer to data sources, aiming to reduce latency, conserve bandwidth, and provide real-time processing. They highlighted the heterogeneity of edge environments, the need for scalable management, and the critical role of load balancing to ensure efficient task distribution across diverse devices. Their work laid the foundation by identifying open challenges such as resource allocation, reliability, and seamless coordination between cloud and edge layers. The research by [5] emphasized how immersive technologies such as augmented reality, self-driving cars, and mobile interactive systems demand ultra-low latency that traditional cloud models cannot guarantee. By stressing real-time responsiveness, they provides a strong rationale for algorithms like EWMA that prioritize server response performance. The review by the authors [6] and his team systematically reviewed mobile edge computing, identifying resource management, task offloading, and network optimization as central challenges. The survey presented traditional

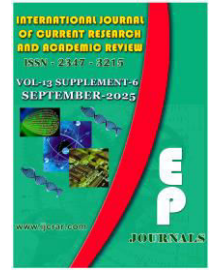


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strategies like Round Robin and Least Connections as baseline solutions but noted their limitations under dynamic mobile network conditions. The authors suggested that adaptive and context-aware balancing mechanisms are essential to maintain performance; particularly in environments where workload demand and connectivity fluctuate. The study by the authors [7] introduced a predictive balancing model that employs machine learning to anticipate workload changes and proactively assign tasks.

Table 1. Literature survey

Reference	Features
[4]	Introduced edge computing to reduce latency and bandwidth usage by processing near data sources. Highlighted heterogeneity, scalability, and load balancing challenges.
[5]	Emphasized low-latency demands of AR, autonomous systems, and mobile computing. Advocated latency-aware policies like EWMA for responsive balancing.
[6]	Surveyed MEC, identifying resource management and offloading as key issues. Noted RR and LC as baselines but inadequate under dynamic mobile networks.
[7]	Proposed ML-based predictive balancing using monitoring data. Improved utilization and reduced tail-latency compared to static schedulers.
[8]	Mapped edge–cloud continuum and optimization goals (latency, bandwidth, reliability). Recommended telemetry-driven balancing with monitoring tools.
[9]	Compared balancing strategies (RR, LC, EWMA). Highlighted trade-offs between fairness, adaptability, latency sensitivity, and computational overhead.
[10]	Proposed QoS-aware load balancing using multiple metrics (latency, throughput, SLA compliance). Advocated service differentiation in scheduling decisions.
[11]	Defined a layered fog/edge architecture emphasizing scalability, reliability, and security. Supported distributed load-balancer placement and failover paths.
[12]	Developed improved balancing considering server capacity and performance history. Used EWMA-like smoothing to handle high traffic stably.
[13]	Presented early industry vision of fog computing. Highlighted bandwidth reduction, cost savings, and real-time analytics as drivers of edge adoption.

The authors [8] mapped the edge–cloud continuum, identifying the interplay of latency, bandwidth, and reliability as core optimization targets. Latency-sensitive approaches (response-

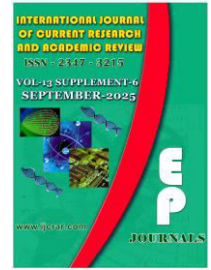


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time/EWMA) are developed by the author [9] and concluded EWMA excels in latency-critical cases but requires monitoring.

In [10], the authors proposed a QoS-aware load balancing approach that incorporates multiple performance metrics such as latency, throughput, and SLA compliance to optimize task distribution in edge environments.. The OpenFog Reference Architecture provided a standardized framework for fog and edge computing, defining principles such as scalability, security, and reliability [11]. It proposed a layered approach, where load balancing can be distributed across multiple tiers to prevent single points of failure. The improved load balancing algorithm designed by Authors [12] considers both the real-time capacity and performance history of servers. By incorporating performance smoothing similar to EWMA, their approach achieved more stable request routing, avoiding frequent oscillations under high traffic conditions. The researchers [3] offered an early industry-driven perspective, introducing fog computing as an extension of cloud that brings computation closer to IoT devices. It described how localized processing reduces backhaul bandwidth and operational costs while enabling real-time analytics. The research work done by the authors is listed in the Table 1. Literature survey

Methodology

The methodology for this research work involves the design, development, and evaluation of adaptive load balancing algorithms within an edge computing environment.

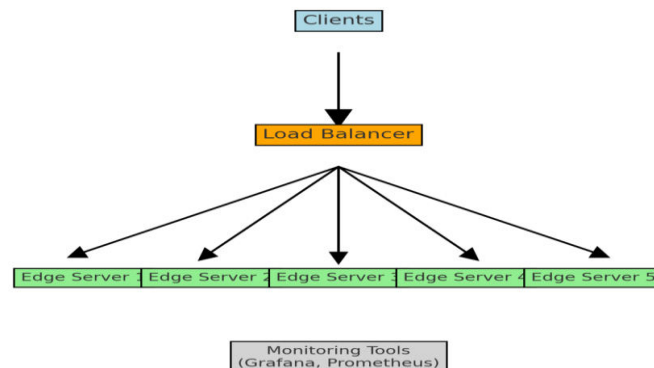


Figure. 1 Working of Load Balancer in Edge Servers



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The overall goal is to optimize resource utilization, minimize latency, and enhance fault tolerance while ensuring scalability in real-world edge deployments. The working of Load Balancer in Edge Servers is referred in Figure 1.

Work Flow

The edge computing environment is structured with five distributed edge servers in a multi layered approach, each positioned at different network locations in close proximity to data sources such as IoT devices, sensors, and user applications. This distributed placement ensures that data processing occurs nearer to the point of generation, thereby reducing communication delays and network congestion. At the core of the system lies a centralized load balancer, which serves as the intelligent decision-making unit responsible for dynamically routing incoming client requests to the most appropriate edge server. The routing decision is based on the chosen load balancing algorithm, which considers factors such as server workload, response time, and overall resource availability. To replicate a realistic deployment scenario, the servers are interconnected through a high-speed local network, enabling seamless data exchange and coordination. Furthermore, the architecture integrates real-time monitoring and analytics tools that continuously track performance metrics, including latency, throughput, and resource utilization. These insights not only support adaptive load balancing decisions but also facilitate detailed performance evaluation, system tuning, and scalability testing.

Key Architectural Features

The proposed edge computing environment is designed with built-in fault tolerance, ensuring system reliability by automatically rerouting client requests to the remaining active servers in the event of a server failure. This resilience minimizes service disruption and maintains continuous availability of applications. By processing data and executing tasks closer to the end-users, the framework further guarantees low latency, effectively reducing round-trip times and enhancing the overall responsiveness of latency-sensitive applications. The workflow of the research work are shown in Figure 2



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Research Contribution

This paper specifically focuses on the design, implementation, and evaluation of adaptive load balancing algorithms in an edge computing environment. Load balancing plays a crucial role in ensuring that computational tasks and requests are efficiently distributed across multiple servers or edge nodes. Without effective load balancing, some servers may become overloaded while others remain underutilized, leading to performance bottlenecks, increased latency, and reduced reliability.

To address this challenge, three key algorithms are implemented and compared. The following are the three algorithms compared.

Round robin [13]

A simple and fair scheduling approach where client requests are assigned to servers in a circular order. Ensures even distribution but does not account for variations in server workload or capacity. Round Robin serves as a baseline to measure fairness in distribution. In Edge Computing RR acts as a baseline algorithm to measure performance improvements of more adaptive techniques

Least Connections [14]

Dynamically assigns requests to the server with the fewest active connections. More adaptive than Round Robin, as it considers current server load. Least Connections provides adaptability under fluctuating workloads, ensuring no single server becomes a bottleneck. Least Connections algorithm is referred as LC in this research work

Fastest Response EWMA [15]

A latency-sensitive approach that routes requests based on historical server response times. The Fastest Response EWMA (Exponentially Weighted Moving Average) algorithm is a latency-aware and intelligent load balancing technique. It assigns requests to the server with the lowest predicted response time, calculated using historical performance data. The lowest predicted response time can be chosen by (1)

$$EWMA = \alpha \times \text{CurrentResponseTime} + (1 - \alpha) \times \text{PreviousEWMA} \text{ -----(1)}$$

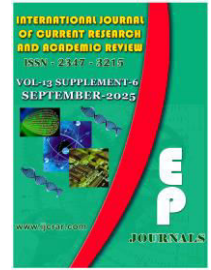


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The algorithm for Fastest Response EWMA are stated below

1. Continuously measure each server's response time after processing requests.
2. Update the EWMA for each server using the above formula.
3. Assign the incoming request to the server with the lowest EWMA value.
4. Repeat the process for subsequent requests.

Experimental Setup and Implementation Details

In this research work, a simulated edge computing environment with multi-layered edge servers was created. The above three algorithms were deployed for handling client requests. The performance was monitored using dashboard. The metric latency was measured, under varying load conditions.

Flask framework was used for simulating servers and load balance. Venv containers were used to emulate multiple edge servers with varying capacities for network simulation. Custom scripts were developed to generate client requests at different rates such as normal, peak, and heavy surge conditions to simulate the traffic.

Performance Evaluation

The performance of the system was evaluated using the latency which is used for measuring the time taken to process and respond to requests. The performance comparison of the various algorithms are shown in Figure 3. The latency analysis highlights the impact of different load balancing algorithms on system response times. Without any load balancing mechanism, the average latency was recorded at 250 ms, primarily due to uneven workload distribution and server overload.

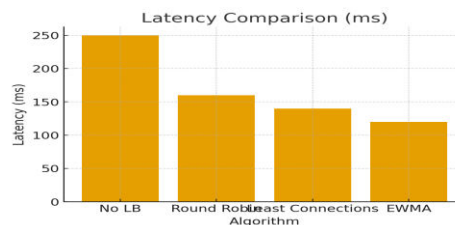


Figure 3. Latency comparison between the three algorithms



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Implementing the Round Robin algorithm reduced latency to 160 ms, as requests were evenly distributed among servers, though it did not account for variations in server load. The Least Connections approach further improved performance, achieving 140 ms latency by dynamically routing requests to the servers with fewer active connections, thereby balancing workloads more effectively. The best performance was observed with the Fastest Response EWMA algorithm, which achieved the lowest latency of 120 ms by adaptively directing requests to the server with the quickest response times, ensuring more efficient utilization of resources and faster client responses.

Conclusion and Future Scope

This research demonstrates that edge computing combined with adaptive load balancing significantly enhances performance, scalability, and cost efficiency. By employing the RR, LC, and EWMA algorithms, the system achieved notable reductions in latency, thereby positioning adaptive load balancing as a key enabler for next-generation distributed systems. Future directions include scaling the system beyond five servers in a multi layered architecture to support enterprise-level deployments, integrating machine learning techniques for predictive load balancing, to anticipate traffic patterns more effectively and practicality of the proposed approach in large-scale heterogeneous environments. Additionally, future work focuses on designing a systematic method to measure scalability across different workload and improve overall performance of the edge servers.

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Full Length Article

IJCRAR/FL/63

Blockchain-Driven Framework for Efficient and Transparent Health Insurance Claims Management

Dr. Namrata Nagpal*

AIIT, Amity University Uttar Pradesh, Lucknow Campus, India

Abstract

The health insurance claim process is often slowed by intermediaries, excessive paperwork, and lengthy verification steps, leading to inefficiencies, higher costs, and frustration for stakeholders. Blockchain technology, with its decentralized and immutable ledger, provides an opportunity to overcome these challenges. This paper presents a blockchain-based framework that leverages smart contracts to automate health insurance claims management. The proposed system enhances efficiency, transparency, and security while reducing manual intervention and mitigating risks of fraud. Smart contracts embedded in the blockchain validate claims automatically by executing predefined rules aligned with policy conditions, treatment records, and medical data. Secure data-sharing protocols ensure the privacy and integrity of sensitive patient and insurance information, while standardized data formats address interoperability issues across insurers, healthcare providers, and policyholders. The paper discusses the framework's technical design, implementation, and performance evaluation. It also examines potential challenges, including scalability, regulatory compliance, and adoption barriers. By harnessing blockchain's capabilities, the proposed system demonstrates how health insurance claims can be processed more efficiently and reliably, creating a patient-centered, cost-effective model. This work highlights the potential of blockchain-enabled smart contracts to transform health insurance claims management and contribute to a more transparent and trusted healthcare ecosystem.

Keywords: Blockchain, health insurance, smart contracts, healthcare, artificial intelligence

Introduction

The healthcare industry is undergoing a digital transformation aimed at improving efficiency, reducing costs, and enhancing the quality of services. One of the most promising innovations driving this change is the integration of blockchain technology and smart contracts to automate and optimize the management of health insurance claims. Traditional claims processing is often complex, time-consuming, and prone to errors, leading to delays, disputes,



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and increased administrative costs. Additionally, concerns related to data privacy, fraud, and transparency further exacerbate these inefficiencies.

Blockchain-based smart contracts present a transformative solution by automating the claims process while ensuring greater transparency, security, and accuracy. Blockchain's decentralized, immutable ledger records every transaction in a secure, transparent manner, accessible only to authorized parties and resistant to tampering.

Smart contracts are nothing but self-executing agreements that are written in code and they automatically trigger actions based on predefined conditions. In the context of health insurance, this could include automatic approval or rejection of claims once the relevant criteria are met.

This innovative approach has the potential to significantly reduce administrative costs, combat fraud, enhance data privacy, and ultimately improve customer satisfaction in the health insurance sector. By leveraging the decentralized nature of blockchain, stakeholders such as patients, healthcare providers, insurance companies, and regulators can interact on a shared, transparent platform that fosters trust and accountability, all without the need for intermediaries. This paper explores the application of blockchain-enabled smart contracts for automating health insurance claims management, examining their key features, benefits, challenges, and their potential to reshape the future of health insurance administration.

Understanding Blockchain Technologies & Smart Contracts

Blockchain technology and smart contracts are two interrelated concepts that have gained significant attention across various industries due to their potential to revolutionize how data is handled, processed, and verified in a decentralized and secure manner. Blockchain is essentially a decentralized digital ledger that securely records transactions across multiple computers, making it extremely difficult to hack or alter. Unlike traditional centralized systems where data is stored on a single server or database, a blockchain distributes the data across a network of nodes (computers), ensuring redundancy and increasing security. Key characteristics of blockchain technology include:



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- Decentralization: No single entity controls the blockchain. Instead, the data is distributed across multiple participants (nodes), ensuring that no one person or organization can manipulate the system.
- Immutability: A transaction once recorded on the blockchain cannot be deleted or altered. This is achieved through cryptographic hashing, ensuring that the integrity of the data is maintained over time.
- Transparency: Since all participants in the blockchain network have access to the same data, transactions are transparent and traceable, allowing anyone with the necessary permission to review the data.
- Security: Blockchain uses advanced cryptographic techniques to ensure that transactions are secure and that only authorized participants can access or modify the information.

A smart contract is a self-executing agreement where the terms are embedded directly in code. It automatically enforces and carries out the contract's terms once specified conditions are met. These contracts are commonly hosted on blockchain platforms such as Ethereum. The key features of Smart contracts can be summarized as follows:

- Autonomous Execution: Once deployed on a blockchain, smart contracts automatically execute predefined actions based on the contract's code. For example, a smart contract could automatically transfer funds from one party to another when a certain condition is met, like confirming the delivery of goods.
- Transparency and Trust: Just like blockchain, smart contracts are transparent and immutable. Once written and deployed, they cannot be altered, ensuring that both parties can trust the contract's execution without relying on a third party.
- Efficiency and Cost Reduction: Smart contracts simplify processes and lower costs by eliminating intermediaries such as lawyers, banks, and notaries. The contract terms are programmed into the blockchain, enabling automatic execution once the specified conditions are fulfilled.
- Security: The decentralized nature of blockchain and the cryptographic methods used in smart contracts ensure that they are secure and resistant to tampering or fraud.

Blockchain serves as the foundation for smart contracts, as it provides the necessary environment for storing, executing, and securing the contract's code. Smart contracts, in turn,



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leverage blockchain's transparency, immutability, and decentralization features to operate autonomously and securely.

Advantages of Blockchain and Smart Contracts

1. Decentralization: No need for intermediaries, reducing costs and inefficiencies.
2. Security: Blockchain's cryptographic features make data and contracts tamper-proof.
3. Transparency: All parties involved ensure the trust by seeing the status and the contract terms.
4. Efficiency: Automation reduces delays and eliminates the need for manual intervention.
5. Cost-effective: Reduces the need for third parties like brokers, notaries, or lawyers.

Challenges and Limitations

1. Scalability: Public blockchains like Ethereum face scalability issues, as transactions can become slow and costly when network congestion occurs.
2. Immutability Risks: While immutability is a key feature, it can also be a double-edged sword. If errors are found in a smart contract after it's deployed, they cannot be easily corrected.
3. Legal Recognition: In many jurisdictions, smart contracts have not yet been fully recognized as legally binding, which could present challenges for adoption in traditional sectors.
4. Complexity: Writing smart contracts can be complex, requiring developers to understand both legal terms and technical programming languages.

Automating Health Insurance Claims Management Using Blockchain & Smart Contracts

Smart contracts can significantly enhance Automated Health Insurance Claims Management by streamlining and automating the claims process, reducing fraud, and increasing transparency and efficiency. In the context of automated health insurance claims management, smart contracts streamline and automate key processes, ensuring faster, more transparent, and efficient claims handling. By utilizing blockchain technology, smart contracts enable secure, real-time verification of claims, automatic payment execution, and an immutable audit trail that enhances trust and reduces the potential for fraud. This innovation not only lowers operational costs but also improves customer satisfaction by expediting claims resolution and minimizing



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disputes. In this context, smart contracts have the potential to revolutionize the health insurance industry, offering a more efficient and secure way to manage claims while ensuring that both insurers and policyholders benefit from increased transparency and reduced friction in the claims process.

Benefits of Applying Blockchain in Automated Health Insurance Claims Management

1. Automation of Claims Processing - Smart contracts automate the entire claims process, from claim submission to payment. When a policyholder submits a claim (e.g., for medical expenses), the smart contract can automatically:
 - Verify the claim details against the policy terms (such as coverage limits and eligibility).
 - Trigger payment to the healthcare provider or the policyholder once the claim is validated, reducing the need for manual intervention.
2. Increased Transparency and Trust: Smart contracts are executed on a blockchain, which provides an immutable and transparent record of every transaction. This ensures:
 - All parties (policyholders, insurers, healthcare providers) can track and verify the status of claims.
 - Full transparency reduces the potential for disputes and builds trust between stakeholders.
3. Reduced Fraud and Errors: The decentralized and immutable nature of blockchain prevents unauthorized changes to claims data. This ensures:
 - Claims are validated against predefined rules, reducing the chances of fraud, such as submitting duplicate claims or inflating medical costs.
 - Errors in manual processing, like incorrect claim approvals or payments, are minimized by automating the process.
4. Faster Claims Resolution: Smart contracts enable real-time processing of claims. This is achieved by:
 - Automating verification, approval, and payment steps, eliminating manual delays.
 - Providing quicker claims resolution and faster payouts to healthcare providers or patients.
5. Cost Efficiency: By reducing the need for intermediaries (e.g., claims adjusters or administrators), smart contracts lower administrative costs for insurers. Additionally:
 - Claims are processed more quickly, reducing the overhead associated with lengthy claim evaluations and paperwork.



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- Less reliance on human intervention leads to fewer errors and disputes, reducing operational costs.
- 6. Enhanced Data Security and Privacy: Smart contracts and blockchain technology ensure that claims data is encrypted and securely stored. Only authorized parties can access this data, improving:
 - Data privacy for policyholders and healthcare providers.
 - Compliance with regulations (e.g., HIPAA in the U.S.) regarding the secure handling of personal health information.
- 7. Improved Customer Experience: Transparency: Policyholders can monitor the progress of their claims and receive updates in real time.
 - Efficiency: Faster claim processing and payment contribute to higher customer satisfaction and loyalty.
- 8. Compliance and Auditing: Smart contracts can be programmed to automatically comply with insurance policies and regulatory requirements, ensuring:
 - Claims are processed according to legal standards.
 - A transparent audit trail is available for regulators or internal audits, making it easier to track the claims process and verify compliance.

Conclusion

Blockchain-enabled smart contracts hold immense potential for transforming automated health insurance claims management by addressing many of the challenges faced by traditional systems. By automating claims verification, approval, and payment processes, smart contracts reduce administrative overhead, eliminate errors, and enhance efficiency. The transparency and immutability of blockchain ensure that all stakeholders—patients, healthcare providers, and insurers—can track and verify claims in real time, fostering trust and reducing fraud.

In summary, smart contracts offer numerous advantages for Automated Health Insurance Claims Management by automating claims verification and payments, enhancing transparency, reducing fraud, ensuring faster processing, and improving overall efficiency. These benefits not only reduce costs but also create a more secure and user-friendly experience for policyholders and insurers alike.



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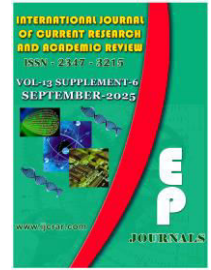


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Full Length Article

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A Review of Artificial Intelligence's Role In Networking

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Abstract

The growing complexity of digital infrastructures, fuelled by the rise of Internet of Things (IOT) devices, cloud computing, and advanced communication systems, creates considerable challenges for managing networks. Traditional, manual approaches are no longer adequate to meet the evolving demands of modern networks. This paper explores how Artificial Intelligence (AI) is transforming network engineering, shifting from rule based, and manual systems to fully automated, AI-powered operations. Technologies like machine learning, deep learning, and reinforcement learning provide real-time analytics, traffic control, anomaly detection, and predictive insights, significantly boosting network performance, security, and reliability. Additionally, it delves into how this shift is altering the skill set required of network engineers, placing greater emphasis on expertise in AI, machine learning, and data analytics. The paper also examines how AI-driven frameworks, such as Software Defined Networking (SDN) and Network Function Virtualization (NFV), enhance network flexibility and scalability. Ultimately, it underscores the essential role of network engineers in integrating AI technologies to maintain the security, efficiency, and resilience of digital infrastructures, while highlighting the need for ongoing professional development to navigate the AI-driven landscape.

Keywords: Digital infrastructures, Software Defined Networking (SDN) and Network Function Virtualization (NFV)

Introduction

As the worldwide communications industry evolved to a new generation nearly every decade, every generation has initiated a revolution in the communications ecosystem. The fourth industrial revolution is driven by developments in electrical power, mechanical, and information technologies. Enhancing and changing the field of the digital economy (Shen et al., 2024). Artificial intelligence (AI) is a key element of



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this revolution. Determining what "I"-intelligence is is one of the most difficult challenges when attempting to explain artificial intelligence (AI) to a lay audience. While the "artificial" component is rather straightforward, intelligence is a complex idea. The ability of a computational system to perform tasks that typically require human intelligence is known as artificial intelligence (AI). Numerous cognitive functions, including language comprehension, learning, reasoning, problem-solving, and perception, are covered by these exercises. This idea emphasizes the ability of AI systems to mimic more and replicate these mental processes more so than test results. The third wave of AI prosperity is being driven by the proliferation of deep learning techniques. Computer vision, natural language processing, multimedia creation, medical applications, and human genetics are just a few of the numerous fields where artificial intelligence has demonstrated significant effectiveness. According to the deployment of the next generation of communication networks, artificial intelligence (AI) enables a change from reactive to proactive data-driven operations, hence enhancing network performance, security, and management. For example, the telecom sector acknowledges AI as a potential evolving application for 5G and possibly 6G networks and employs it to optimize communication-network resources from the perspective of communications and network engineering. AI is expected to facilitate the transition from networked devices to intelligent systems in 6G networks. The current communication infrastructure is gradually getting better as the 6G network develops (Meena et al., 2022). The introduction of 6G technology will make it possible to develop and customize a sophisticated toolkit (Dao, 2023). (Firouzi et al., 2022) state that integrating edge AI into a management system aids in making it possible to administer complex integrations methodically. Researchers have already focused on developing the 6G networking framework, even if the deployment and practical application of 5G technology are still ongoing on a global scale (Chavhan and Assessments, 2022). Real-time analytics, anomaly detection, and predictive insights are just a few of the aspects of network management that are improved by AI-driven networking. It improves the efficiency of routing, protocol design, and security protocols. Among other crucial responsibilities, network engineers must manage cybersecurity concerns, adjust to new technology, and maintain and improve computer systems.

Methodology

Software Defined Networking (SDN) is an approach to computer networking that enables centralized, programmable network control by separating the control plane (which decides where traffic is sent) from the data plane (which forwards traffic to its destination). This abstraction makes the network more flexible, automated, and easier to manage, especially in large-scale or dynamic environments like data centers and cloud infrastructures. Network Function Virtualization (NFV) is a network architecture concept that decouples network functions (like firewalls, load balancers, routers, etc.) from dedicated hardware appliances and runs them as virtualized software instances on standard



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servers. This enables flexible, scalable, and cost-effective deployment and management of network services.

Case Studies of Companies Adopting Ai-Enhanced Networking

1. Recent case studies show that AI-enhanced networking is transforming several businesses. For instance, well-known telecom firms such as Verizon (USA) and AT&T (USA) have used AI algorithms to forecast peak traffic levels and dynamically change network settings. By including machine learning models to examine real-time and historical traffic data, these businesses have efficiently allocated bandwidth, lowered latency, and significantly lowered service degradation during peak demand times. One operator claimed a significant rise in network efficiency, which led to improved customer happiness and a competitive market edge (Agarwal et al., 2024; Sahin and Sathya, 2024).
2. Financial sector companies such as JPMorgan Chase (USA), HSBC (UK) and Bank of America (USA) have installed AI-driven anomaly detection systems inside their network architecture to strengthen cybersecurity initiatives (Eswaran et al., 2025; Popoola; Tayyab et al., 2025). By surpassing traditional, signature-based intrusion detection techniques, these companies are now able to spot zero-day vulnerabilities and advanced persistent attacks in real-time. By means of ongoing learning from changing data patterns, these systems lower false positives and hasten incident response procedures, so protecting sensitive information more precisely (Ajayi et al., 2024; Lawal, 2025).
3. E-commerce behemoths and cloud providers such as Alibaba (China) and Amazon (USA) are also leading this technological change. They handle complex virtualised settings, including SDN and NFV, using AI-enhanced networking technologies. These systems use predictive analytics and reinforcement learning to automate regular activities such as network monitoring, resource allocation, and fault correction (Rao, 2018; Zhang et al., 2019). This strategy eventually results in real advantages such as a reduction in outage and cost savings. Case studies from these industries have highlighted the practical value of AI integration by showing significant gains in total cost of ownership (TCO) and bandwidth use.
4. Together, these case studies show that the application of AI-enhanced networking is a pragmatic solution that produces measurable benefits rather than just a theoretical evolution. Companies in many sectors are seeing improved operating efficiency, better security, and the ability to change with the times to meet modern digital infrastructure needs. The use of AI in network management is expected to provide new benchmarks for proactive threat management, scalability, and dependability, hence enabling a robust and flexible future in telecoms as AI keeps evolving (Thakur et al., 2024).



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Future Trends and Predictions

The use of AI in networking is poised to revolutionize the management and optimization of digital infrastructures. There will be a gradual transition from static, manually built systems to AI technologies as network management protocols advance and become more integrated with AI technology entities that are dynamic and self-adaptive (Krenn et al., 2023). It is anticipated that future networks would exhibit self-optimizing capabilities, in which machine learning algorithms continuously analyze performance metrics, predict issues, and automatically adjust parameters to maintain optimal data flows. According to Dandamudi et al. (2025), this modification guarantees networks that are more resilient, resource-efficient, and able to manage the exponential development of connected devices, guaranteeing consistent connectivity even during peak hours. Alongside the shift towards resource optimization and self-management, artificial intelligence is expected to revolutionize network environment cybersecurity. AI-driven security and threat management systems that can respond to incidents and identify anomalies in real time are most likely to be a feature of networks in the future. The ability to identify minute deviations from routine activity and lower hazards before they worsen is made possible by these systems' ongoing learning from fresh data (Alshahrani, 2023).

Threats and maintaining the integrity of data. It is also anticipated that the use of AI will stimulate the creation of innovative networking topologies that combine cutting-edge software-defined solutions with traditional hardware. For example, combining AI with NFV and SDN will enable the development of programmable, scalable networks that can support a wide range of applications, such as 5G and the Internet of Things. As these technologies advance, networks will become more flexible by rerouting traffic and allocating resources dynamically based on predictive analysis and real-time monitoring. This level of automation reduces the need for human involvement and speeds up response to critical network problems.

Anticipated to greatly reduce operating overhead (Barakabitze et al., 2020). The employment market and the skill requirements of network professionals will likewise be drastically altered by the development of AI in networking. As network administration and routine troubleshooting become increasingly automated, there will be an increasing demand for network engineers with advanced expertise in data analytics, machine learning, and artificial intelligence. In organizations responsible for the design, integration, and management of smart network systems, positions such as AI Network Architect and Network Automation Engineer will be. Additionally, as AI-driven networking continues to advance, integration problems and ethical concerns—such as bias and transparency in algorithmic decision-making—as well as the requirement for continuous upskilling will need to be resolved (Bala et al., 2023).

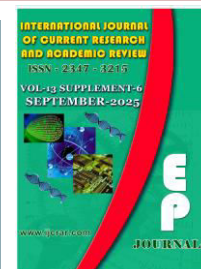


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Conclusion

The use of AI into network engineering signifies a fundamental shift in the industry rather than just a little technological advancement. This study examined the complex effects of AI on network security, administration, and the changing role of network engineers. The light of new technology such as 6G. A fundamental reassessment of the abilities and duties of network engineers is required as a result of the paradigm change from conventional, manual network management to AI-driven, automated solutions. The investigation has highlighted the ways in which AI-driven automation is improving network performance, strengthening security protocols, and simplifying repetitive operations. AI maximizes network resilience and efficiency by utilizing machine learning, deep learning, and reinforcement learning to provide real-time analytics, predictive maintenance, and adaptive security procedures. However, this automation enhances network engineers' responsibility to include strategic oversight and complex problem solutions, not lessening their significance. The changing environment demands that network engineers have a much wider range of skills. In order to manage and secure complex digital infrastructures, proficiency with AI technologies, data analytics, and machine learning is becoming essential. This change emphasizes how crucial professional development and ongoing education are to network engineers' continued relevance in an AI-driven world. Additionally, the effects of AI integration on employment in the field of network engineering have been emphasized in this research. Even though AI automates repetitive tasks, it also opens up new possibilities that call for highly skilled technical knowledge. The capacity to create, execute, and oversee AI-driven Networking platforms and technologies turn into an invaluable resource that promotes creativity and propels the growth of strong digital ecosystems. Essentially, network engineering's future is closely tied to the development of artificial intelligence. With the requisite abilities and expertise, network engineers play a critical role in enabling the smooth integration of AI technologies, guaranteeing the dependability and security of digital infrastructures. The role of network engineers will continue to change as we progress toward more intelligent and connected networks, necessitating flexibility, creativity, and a proactive attitude toward adopting rising technologies. The construction of safe, effective, and sustainable digital environments that meet the constantly increasing needs of our globalized society will depend on how well this changing terrain is navigated.

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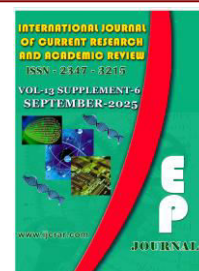


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Full Length Article

IJCRAR/FL/65

A Survey on Artificial Intelligence

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Abstract

The study of computational models of problem solving, where the problems to be solved are as complicated as those handled by humans, is known as artificial intelligence (AI). The field of artificial intelligence studies ways to help computers perform tasks that humans now perform more effectively. It is the field of computer science that seeks to develop machine intelligence. Artificial intelligence is another name for the study and creation of intelligent agents. Characteristics like thinking, understanding, planning, learning, communication, perception, and the capacity to move and handle objects are among the main issues with artificial intelligence. The goal of this paper is to examine artificial intelligence (AI) approaches from the perspective of how they can be used in all engineering-related domains. It focusses specifically on artificial intelligence approaches that have been established or are being researched and can be used to solve issues related to certain processes. A comparative analysis of techniques and their applications is highlighted in this research.

Keywords: perception, logic, computer science, manipulative objects

Introduction

The capacity to solve problems is a sign of intellect. When a mouse tries to find or get the slice of cheese in the image's upper right corner, it can solve this difficulty in a number of ways. We can conclude that the mouse has sufficient intelligence to solve the issue. Therefore, the ability to solve problems shows intelligence. Different types and levels of intelligence can be found in humans, many animals, and certain computers. Intelligence is the computational



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component of the capacity to accomplish goals in the world. Computer science, physiology, and philosophy are all combined to create artificial intelligence, or AI for short. AI encompasses a wide range of disciplines, including expert systems and machine vision. The development of computers with the ability to "think" is the commonality among the various branches of artificial intelligence. Creating systems that behave like the human brain, which is composed of billions of neurones and is arguably the most complex material in the universe, is one of the most difficult tasks facing professionals.

Problems of Artificial Intelligence

Deduction, reasoning, problem solving

Early AI researchers developed algorithms that imitated the step-by-step reasoning that human beings use when they solve puzzles, play board games or make logical deductions. By the late 80s and 90s, AI research had also developed highly successful methods for dealing with uncertain or incomplete information, employing concepts from probability and economics. For difficult problems, most of these algorithms can require enormous computational resources – most experience a "combinatorial explosion": the amount of memory or computer time required becomes astronomical when the problem goes beyond a certain size. The search for more efficient problem solving algorithms is a high priority for AI research.

Human beings solve most of their problems using fast, intuitive judgments rather than the conscious, step-by-step deduction that early AI research was able to model. AI has made some progress at imitating this kind of "sub-symbolic" problem solving: embodied approaches emphasize the importance of sensor motor skills to higher reasoning; neural net research attempts to simulate the structures inside human and animal brains that gives rise to this skill.

Knowledge representation

Knowledge representation and knowledge engineering are central to AI research. Many of the problems machines are expected to solve will require extensive knowledge about the world. Among the things that AI needs to represent are: objects, properties, categories and relations between objects; situations, events, states and time; causes and effects; knowledge



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about knowledge (what we know about what other people know); and many other, less well researched domains. A complete representation of "what exists" is an ontology (borrowing a word from traditional philosophy), of which the most general are called upper ontology.

Planning

Intelligent agents must be able to set goals and achieve them. They need away to visualize the future (they must have a representation of the state of the world and be able to make predictions about how their actions will change it) and be able to make choices that maximize the utility (or "value") of the available choices. In some planning problems, the agent can assume that it is the only thing acting on the world and it can be certain what the consequences of its actions may be. However, if this is not true, it must periodically check if the world matches its predictions and it must change its plan as this becomes necessary, requiring the agent to reason under uncertainty.

Learning

Machine learning has been central to AI research from the beginning. Unsupervised learning is the ability to find patterns in a stream of input. Supervised learning includes both classification (be able to determine what category something belongs in, after seeing a number of examples of things from several categories) and regression (given a set of numerical input/output examples, discover a continuous function that would generate the outputs from the inputs). In reinforcement learning the agent is rewarded for good responses and punished for bad ones. These can be analyzed in terms of decision theory, using concepts like utility. The mathematical analysis of machine learning algorithms and their performance is a branch of theoretical computer science known as computational learning theory.

Natural language processing

Natural language processing gives machines the ability to read and understand the languages that the human beings speak. Many researchers hope that a sufficiently powerful natural language processing system would be able to acquire knowledge on its own, by reading

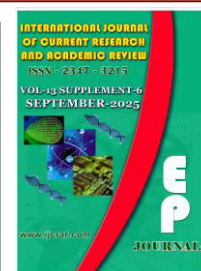


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the existing text available over the internet. Some straight forward applications of natural language processing include information retrieval (or text mining) and machine translation.

Motion and Manipulation

ASIMO uses sensors and intelligent algorithms to avoid obstacles and navigate stairs. The field of robotics is closely related to AI. Intelligence is required for robots to be able to handle such tasks as object manipulation and navigation, with sub-problems of localization (knowing where you are), mapping (learning what is around you) and motion planning (figuring out how to get there).

Perception

Machine perception is the ability to use input from sensors (such as cameras, microphones, sonar and others more exotic) to deduce aspects of the world. Computer vision is the ability to analyze visual input. A few selected sub problems are speech recognition, facial recognition and object recognition.

Creativity

A sub-field of AI addresses creativity both theoretically (from a philosophical and psychological perspective) and practically (via specific implementations of systems that generate outputs that can be considered creative).

Approaches to Artificial Intelligence

AI research is not guided by any recognised unifying theory or paradigm. There are several topics on which researchers disagree. These are some of the oldest questions that still haven't been resolved: Can high-level symbols, like words and concepts, be used to replicate intelligence? Or is "sub-symbolic" processing necessary? Should artificial intelligence research animal physiology or human psychology to mimic natural intelligence? Or is human biology as unrelated to AI research as the biology of birds is to the engineering of aeroplanes? Is it possible to characterise intelligent behaviour using elegant, straightforward principles like optimisation



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or logic? Or does the development of artificial intelligence necessitate the resolution of numerous unrelated issues?

A. Brain simulation and cybernetics Researchers studying artificial intelligence get inspiration from the human brain, but there is disagreement about how closely it should be replicated. Numerous researchers investigated the relationship between cybernetics, information theory, and neurology in the 1940s and 1950s. Some of them created devices, such as the Johns Hopkins Beast and W. Grey Walter's turtles, that displayed primitive intelligence through electronic networks. Many of these researchers came together for meetings of the Ratio Club in England and the Teleological Society at Princeton University.

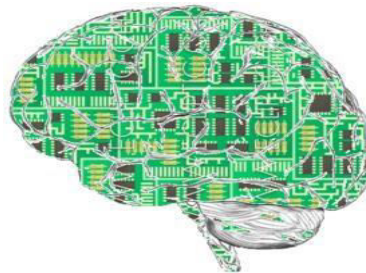


Fig 53.1 Cybernetics example

B. Conventional AI that uses symbols AI research started to investigate the idea that human intelligence may be reduced to manipulating symbols when digital computers were accessible in the middle of the 1950s. Three universities – MIT, Stanford, and CMU – were the focus of the study, and each established a distinct research methodology. These methods of AI were dubbed "good old fashioned AI" or "GOFAI" by John Haugeland.

C. Simulation of cognition The fields of artificial intelligence, cognitive science, operations research, and management science were all founded on the work of economists Herbert Simon and Alan Newell, who investigated and attempted to codify human problem-solving abilities. To illustrate the parallels between human issue solving and the programs (like their "General



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Problem Solver") they were creating, their study team conducted psychological tests. Carnegie Mellon University would be the focal point of this tradition.

D. Simulation of cognition The fields of artificial intelligence, cognitive science, operations research, and management science were all founded on the work of economists Herbert Simon and Alan Newell, who investigated and attempted to codify human problem-solving abilities. Their study team conducted psychological tests to show how human problem-solving is comparable to the programs (such as their "General Problem Solver") they were developing. This tradition, centred at Carnegie Mellon University would eventually culminate in the development of the Soar architecture in the middle 80s.

Logical AI

Unlike Newell and Simon, John McCarthy felt that machines did not need to simulate human thought, but should instead try to find the essence of abstract reasoning and problem solving, regardless of whether people used the same algorithms. His laboratory at Stanford (SAIL) focused on using formal logic to solve a wide variety of problems, including knowledge representation, planning and learning. Logic was also focus of the work at the University of Edinburgh and elsewhere in Europe which led to the development of the programming language Prolog and the science of logic programming.

Topdown approaches

Because of the large storage capacity of computers, expert systems had the potential to interpret statistics, in order to formulate rules. An expert system works much like a detective solves a mystery. Using the information, and logic or rules, an expert system can solve the problem. For example if the expert system was designed to distinguish birds it may have the following as shown in Fig 3.

The traditional view of software development process begins at the requirements specification and ends at testing the software. At each of these stages, different kinds of knowledge (design knowledge at design stage and programming and domain knowledge at the coding stage) are required. At each of the two stages: design and coding, exist a cycle: error



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recognition and error correction. Experience shows that errors can occur at any stage of software development. Errors due to coding may occur because of faulty design. Such errors are usually expensive to correct.

A basic problem of software engineering is the long delay between the requirements specification and the delivery of a product. This long development cycle causes requirements to change before product arrival. In addition, there is the problem of phase independence of requirements, design and codes. Phase independence means that any decision made at one level becomes fixed for the next level. Thus, the coding team is forced to recode whenever there is change in design. Expert system use knowledge rather than data to control the solution process. Knowledge engineers build systems by eliciting knowledge from experts, coding, that knowledge in an appropriate form, validating the knowledge, and ultimately constructing a system using a variety of building tools.

The main phases the expert system development processes are:-

- Planning
- Knowledge acquisition and analysis
- Knowledge design
- Code
- Knowledge verification
- System evaluation

Artificial Intelligence Techniques In Software Engineering (AITSE)

Software Engineering is a knowledge-intensive activity, requiring extensive knowledge of the application domain and of the target software itself. Many Software products costs can be attributed to the ineffectiveness of current techniques for managing this knowledge, and Artificial Intelligence techniques can help alleviate this situation.



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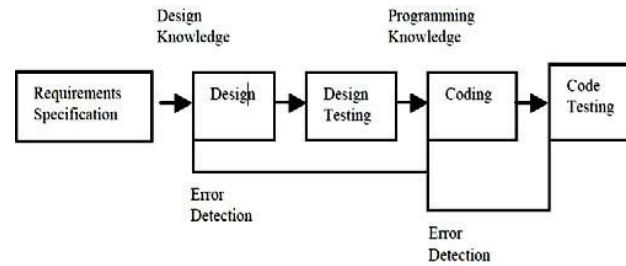
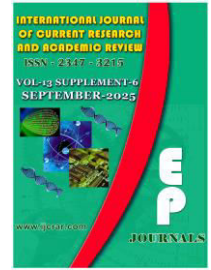


Fig 53.2 Traditional software development process

A. Specific characteristics of intelligent behavior

- Learn from experience and apply the knowledge acquired from experience.
- Handle complex situations.
- Solve problems when important information is missing.
- Determine what is important.
- React quickly and correctly to a new situation.
- Understand visual images.
- Process and manipulate symbols.
- Be creative and imaginative.
- Useheuristics.

Difference Between Natural and Artificial Intelligence

Table 53.1 Difference Between Natural and Artificial Intelligence

Attributes	Natural Intelligence (Human)	Artificial Intelligence (Machine)
The ability to use sensors (eyes, ears, touch, smell)	high	low
The ability to be creative and imaginative	high	low
The ability to learn from	high	low



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experience		
The ability to be adaptive	high	low
The ability to afford the cost of acquiring intelligence	high	low
The ability to use a variety of information source	high	high
The ability to acquire large amount of external information	high	high
The ability to make complex calculations	low	high
The ability to transfer information	low	high
The ability to make a series of calculations rapidly and accurately	low	high

AI Applications

Artificial intelligence has a wide range of uses, particularly in industrialised nations. In reality, most individuals who profit from artificial intelligence's effectiveness take it for granted because it has become such a ubiquitous feature of modern life. Fuzzy logic or "smart" technology has made it possible for devices like air conditioners, cameras, video games, medical equipment, traffic lights, and refrigerators to operate. To handle the massive amounts of data that are essential to their operations, major financial and insurance companies mostly rely on artificial intelligence.

Although its use and practical usefulness are more limited, computer speech recognition has made it feasible to communicate with computers by speaking rather than writing. Another common use is robotics, which is the study and development of robots. Its end goals might range from safety (e.g., fire detection and extinguishment) to research (e.g., Mars rovers) to enjoyment (e.g., robot pets). A branch of artificial intelligence called natural language processing gives computers the comprehension they need to process data that people encode. Computer



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vision teaches machines to understand pictures and scenes. Among its objectives are picture mapping, tracking, and recognition. The domains of medicine, security, surveillance, and military operations all benefit from this use.

A.Current Usage

- There are many applications of artificial intelligence at present. Some of them have been listed here.
- Banks and other financial institutions rely on intelligent software, which provide accurate analysis of the data and helps make predictions based upon that data.
- Stocks and commodities are being traded without any human interference - all thanks to the intelligent systems.
- Artificial intelligence is used for weather forecasting.
- It is used by airlines to keep a check on its system.
- Robotics is the greatest success story, in the field of artificial intelligence. Space crafts are sending by NASA and other space organizations into space, which are completely manned by robots. Even some manufacturing processes are now being completely undertaken by robots. Robots are being used in industrial processes that are dangerous to human beings, such as in nuclear power plants.
- Usage of artificial intelligence is quite evident in various speech recognition systems, such as IBM ViaVoice software and Windows Vista.



Fig 53.3 (a) ASIMO uses sensors and intelligent algorithms to avoid obstacles and navigate stairs. **(b) KISMET**, a robot with rudimentary social skills.



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Fig 53.4 Driverless cars



Fig 53.5 Sofia-an artificial intelligence robot

Advantages and Disadvantages

Advantages

- **Jobs** – depending on the level and type of intelligence these machines receive in the future, it will obviously have an effect on the type of work they can do, and how well they can do it (they can become more efficient). As the level of AI increases so will their competency to deal with difficult, complex even dangerous tasks that are currently done by humans, a form of applied artificial intelligence.
- **They don't stop** – as they are machines there is no need for sleep, they don't get ill, there is no need for breaks or Facebook, they are able to go, go, go! There obviously may be the need for them to be charged or refuelled, however the point is, they are definitely going to get a lot more work done than we can. Take the Finance industry for example, there are constant stories arising of artificial intelligence in finance and that stock traders are soon to be a thing of the past.
- **No risk of harm** – when we are exploring new undiscovered land or even planets, when a



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machine gets broken or dies, there is no harm done as they don't feel, they don't have emotions. Whereas going on the same type of expeditions a machine does, may simply not be possible or they are exposing themselves to high risk situations.

- **Act as aids** – they can act as 24/7 aids to children with disabilities or the elderly, they could even act as a source for learning and teaching. They could even be part of security alerting you to possible fires that you are in threat of, or fending off crime.
- **Their function is almost limitless**—as the machines will be able to do everything (but just better) essentially their use, pretty much doesn't have any boundaries. They will make fewer mistakes, they are emotionless, they are more efficient, and they are basically giving us more free time to do as we please.

Disadvantages for Artificial Intelligence(AI)

- **Over reliance on AI** – as you may have seen in many films such as The Matrix, iRobot or even kids films such as WALL.E, if we rely on machines to do almost everything for us we become very dependent, so much so they have the potential to ruin our lives if something were to go wrong. Although the films are essentially just fiction, it wouldn't be too smart not to have some sort of backup plan to potential issues on our part.
- **Human Feel**– as they are machines they obviously can't provide you with that 'human touch and quality', the feeling of a togetherness and emotional understanding, that machines will lack the ability to sympathise and empathise with your situations, and may act irrationally as a consequence.
- **Inferior** – as machines will be able to perform almost every task better than us in practically all respects, they will take up many of our jobs, which will then result in masses of people who are then jobless and as a result feel essentially useless. This could then lead us to issues of mental illness and obesity problems etc.
- **Misuse**—there is no doubt that this level of technology in the wrong hands can cause mass destruction, where robot armies could be formed, or they could perhaps malfunction or be corrupted which then we could be facing a similar scene to that of terminator (hey, you never know).
- **Ethically Wrong?** – People say that the gift of intuition and intelligence was God's gift to mankind, and so to replicate that would be then to kind of 'play God'. Therefore not right to even attempt to clone our intelligence.



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Conclusion

We must first be ready for change. Our conservative practices impede advancement. AI is a novel development that greatly benefits society. Jobs requiring careful attention to detail and mental acuity can be performed by machines. AI's capacity for learning can complete those tasks, but only if the conservatives in the world are willing to adapt and make it possible. It prompts us to consider how early humanity ultimately came to view the wheel as a useful device that did not diminish its history or customs.

Second, we need to be ready to discover what AI is capable of. The more we use the machines, the less labour we have to do, resulting in fewer human injuries and stress. We must be willing to give AI a chance since humans are a species that learns by doing, and we should view AI as a tool rather than a barrier.

Lastly, we must be ready for AI's worst case scenario. There will undoubtedly be a lot of hitches to iron out with something as revolutionary as AI. We need to be as ready as possible for this new technology because there are a lot of things that can go wrong with a new system.

But despite people's fear of the machines, their potential is limitless. If AI produces a good result in the future, they will recommend whatever we teach it. AI must be trained to be bright, polite, and kind, much like kids. They must exercise wisdom if they are to make significant choices. As citizens, it is our responsibility to ensure that AI programmers maintain objectivity. In order to prevent mishaps in the future, we need ensure that they are performing their duties correctly.

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Full Length Article

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AI-Generated Recommendations: Roles of Language Style and Recommendation Agent

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Abstract

This research investigated the impact of linguistic styles on the acceptance of artificial intelligence (AI)-generated recommendations, using three experiments. Specifically, we considered the use of figurative versus literal language in ChatGPT. The findings of Study 1 indicated that figurative language positively affects visit intention, with imagery vividness serving as a mediator in the underlying process.

Keywords: ChatGPT, AI market, hospitality and travel platforms

Introduction

Artificial intelligence (AI) systems have transformed how consumers access information and make decisions, particularly in hospitality and tourism (Kim *et al.*, 2023a; 2023b). ChatGPT, an advanced AI chatbot developed by OpenAI, has significantly impacted the industry with large language models trained on extensive text data that provide datadriven, contextually rich, and linguistically nuanced suggestions (Ali *et al.*, 2023). The global generative AI market in the travel industry is projected to reach \$3.58 billion by 2032 (Kolesnikov, 2024).

Leading hospitality and travel platforms, such as Expedia and Kayak, have recognized the potential of ChatGPT and used it to enhance the customer booking experience and streamline travel planning (Mauran, 2023). ChatGPT's advanced language-processing



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capabilities can offer personalized recommendations, answer queries, and assist users in planning trips more efficiently. However, integrating generative AI into hospitality and tourism is challenging. A primary concern is the cost associated with adopting such technologies (Vanian & Leswing, 2023) for customized AI-generated trip recommendations.

These recommendations should consider the language, tone, and style preferences of potential customers to ensure effective AI communication and avoid providing misleading information. Nevertheless, ChatGPT's advanced language-processing capabilities not only enable personalized recommendations and efficient trip planning but also represent a novel intersection of linguistic expression and AI-driven suggestions (Baek & Kim, 2023a; Paul *et al.*, 2023).

Previous research suggests a positive impact of human-like characteristics of AI chatbots on acceptance of AI technology (Kim *et al.*, 2024; Pelau *et al.*, 2021), user engagement (Schuetzler *et al.*, 2020), investment behaviors (Baek & Kim, 2023b), and prosocial behaviors (Baek *et al.*, 2022). However, it often disregards the stylistic elements of AI-generated language that influence consumer decision-making.

Figurative language, including metaphors, similes, and personification, plays an important role in human communication, adding depth and emotional resonance (McQuarrie & Mick, 1996). Regarding travel recommendations, figurative language draws consumers' attention and shapes positive attitudes toward destinations (Djafarova, 2017). Kronrod and Danziger (2013) assert that figurative language in online hotel reviews generates more favorable attitudes toward hedonic consumption (e.g., vacation trips) than utilitarian consumption (e.g., business trips). However, the implications of leveraging linguistic techniques for AI-generated recommendations have remained unexplored. This presents a compelling opportunity to investigate how ChatGPT's figurative language affects prospective travelers' responses when seeking travel advice. This study fills this gap by answering the following questions: Does the use of figurative language enhance the persuasiveness of AI travel recommendations? How does the use of figurative language by ChatGPT (vs. a human agent) influence perceptions of recommended travel destinations? This study also examined whether prospective travelers' perceptions of AI human-likeness and recommendation agent types moderate the impact of figurative language on visit intention.



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The study results have several theoretical and practical implications. First, we contribute to the growing body of research on hospitality and travel technology applications (Kim *et al.*, 2023a; 2023b; Shi *et al.*, 2021; Wong *et al.*, 2023) by providing a comprehensive understanding of customer reactions to figurative language in AI-driven communications. Second, we extend the persuasion literature by exploring stylistic language use in human-AI interactions (Kim & Im, 2023; Choi *et al.*, 2019). Practically, this study provides valuable insights for marketers integrating linguistic interfaces into AI-powered recommendation systems by elucidating how figurative language influences travel decision-making. Our findings provide insights for designing generative AI-powered communication strategies for the tourism industry. Marketers can leverage our results to craft more compelling and persuasive AI-generated content by tailoring the language to evoke stronger imagery and emotional connections.

Prior Literature and Hypotheses

Generative AI and Hospitality and Travel Recommendations

Generative AI technologies are revamping the way consumers make decisions (Kumar *et al.*, 2023). Drawing from large datasets, AI technologies instantly provide valuable insights and personalized recommendations to users (De Bruyn *et al.*, 2020; Kotiloglu *et al.*, 2017). Thus, prospective travelers can make informed decisions while significantly reducing their reliance on traditional travel intermediaries.

In the age of AI, ChatGPT has gained popularity among travelers seeking destination information (Kim *et al.*, 2023a; Shin *et al.*, 2023). Many online travel agencies and tourism organizations have integrated ChatGPT plugins into their services to cater to the growing demand for personalized tourism information and recommendations (Dwivedi *et al.*, 2023; Mauran, 2023).

Although prior research has focused on enhancing the quality of these AI recommendation systems within the tourism sector (Kim *et al.*, 2023a; 2023b; Ali *et al.*, 2023), their nuanced language style remains to be analyzed. This is particularly relevant for generative AI, such as ChatGPT, which rely on natural language models to generate humanlike conversations. Understanding how the language style used by these systems affects travel



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decision-making will enable marketers to provide more effective and persuasive recommendations. Table 1 presents empirical literature focusing on applying generative AI in hospitality and tourism. Although previous studies offer some insights into the impact of AI recommendation systems on consumer travel decision-making, there is a significant gap in understanding how linguistic cues in AI-generated recommendations influence destination visit intentions. Specifically, little is known about how consumers react to figurative (vs. literal) language in ChatGPT recommendations. This study aimed to bridge this gap and contribute to the growing body of literature on AI-generated travel recommendations.

Language Style Matters: Figurative Versus Literal Language

Figurative and literal language are two common communication styles. Figurative language—encompassing linguistic techniques such as similes, metaphors, wordplay, and hyperboles—extends beyond the literal meanings of words and conveys additional connotations or meanings (Wu *et al.*, 2017); it employs words and expressions that leverage indirect meanings (Kronrod & Danziger, 2013). Conversely, literal language communicates information clearly and concisely and is devoid of additional interpretations or meanings (Wu *et al.*, 2017); it uses words and expressions according to their dictionary definitions (Kronrod & Danziger, 2013). Examples of literal language include straightforward statements of facts, descriptions of physical objects or actions, and definitions of terms (Kronrod & Danziger, 2013). Figurative language is more imaginative and creative than literal language.

Prior research on language styles suggests the advantage of figurative language in eliciting positive brand attitudes (Phillips & McQuarrie, 2009). Nonetheless, extant literature points out that the effectiveness of figurative language is contingent upon the communication context. For example, Kronrod and Danziger (2013) show that figurative language leads to more positive attitudes toward hedonic rather than utilitarian consumption. However, Wu *et al.*, (2017) find a different pattern of language style effects in online hotel reviews, suggesting the moderating role of the reviewer's expertise level. They indicate that, when a review is posted by a low-expertise reviewer, literal (vs. figurative) language leads to more positive attitudes and reservation intentions. Conversely, no differences in language style were observed when the reviewer possessed high expertise. Similarly, Leung (2021) shows that consumers evaluate longer online reviews written in literal language as more useful than those written in figurative



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language. This variance is explained by language expectancy theory, which suggests that people develop expectations regarding context-specific conversational norms, and these expectations influence the persuasiveness of messages (Burgoon, 1993). Accordingly, when the language style is congruent with the conversational norm of the context, it leads to positive message evaluation and good customer outcomes (e.g., attitude, intentions, and service experience). In this sense, AI-powered agents/robots must be configured to follow conversational norms in order to achieve optimal communication outcomes. Building on this insight, this study explored how language style affects consumer decision-making in the context of AI-generated travel recommendations.

Impact of Figurative Language on Destination Recommendations

Figurative language, perceived as more emotional and affective, is more appropriate for conveying emotional and hedonic experiences than utilitarian language (Gibbs, 2008; Ireland & Pennebaker, 2010; Kronrod & Danziger, 2013). Previous studies have indicated that advertising is more effective when figurative language tactics, such as metaphors and similes, are employed (Chang & Yen, 2013; Phillips & McQuarrie, 2009). This is because consumers expect creative, imaginative, and metaphorical expressions in advertising (Stern, 1988; Phillips & McQuarrie, 2009). Other studies have demonstrated that people use figurative language more when describing emotional (Fussell & Moss, 1998) and hedonic experiences (Kronrod & Danziger, 2013). These findings indicate that figurative language serves as a conversational norm when communicating hedonic and emotional information (e.g., a review of an art gallery) more than functional and utilitarian information (e.g., insurance terms and conditions; Gibbs, 2008; Ireland & Pennebaker, 2010).

This study argues that figurative language is more conversationally normative than literal language in the context of ChatGPT travel destination recommendations. Travel destination decisions are largely hedonic in nature (Hosany & Gilbert, 2010). Destination marketing often relies on emotionally arousing content to convey the experiential qualities of a destination (Ma *et al.*, 2024). This approach is plausible as the effectiveness of destination marketing is determined by the message's ability to evoke emotional and sensory responses in potential travelers (Djafarova, 2017). Figurative language emotionally transports the message recipient to the destination (Rahmani *et al.*, 2019). Therefore, we posit that the use of figurative (vs. literal)



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language in ChatGPT's destination recommendations is more effective in encouraging target destination visit intentions. The following hypothesis is proposed:

H1: Using figurative (vs. literal) language in ChatGPT recommendations leads to stronger visit intention.

Mediating Role of Imagery Vividness

Imagery vividness refers to the extent to which an individual generates detailed mental images in response to advertising and marketing campaigns (Nielsen *et al.*, 2018). A reciprocal relationship exists between the increased use of metaphor and vivid imagery, suggesting that figurative language facilitates the creation of vivid mental images (Stephan *et al.*, 2023; Ye & Mattila, 2022). Carston (2018) suggests that individuals experience mental imagery when they understand linguistic metaphors.

Thus, we postulate that figurative language facilitates the vivid appeal of a destination in the context of generative AI. For instance, ChatGPT describing a beach destination as "having white sand and blue water" may not be convincing, despite its accuracy. Instead, the use of figurative language, such as "the beach caresses your feet while the serene turquoise water washes your concerns away," may elicit vivid mental and emotional images that transport tourists to the recommended destination.

In summary, figurative language, with its rich imagery and emotional power, can emotionally transport a message recipient to a destination (Rahmani *et al.*, 2019). AI generated travel recommendations using figurative language capitalize on human imagination (Khatena & Khatena, 1990), allowing prospective tourists to mentally visualize recommended destinations, thereby fostering stronger visit intentions (Skard *et al.*, 2021). Given the importance of imagery in shaping consumer acceptance of recommended travel destinations, we propose that imagery vividness mediates the effect of figurative language on consumer responses to travel recommendations. Thus, we suggest the following mediation hypothesis:

H2: Imagery vividness mediates the impact of figurative language in ChatGPT recommendations on visit intention.



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Moderating Effect of Perceived AI Human-Likeness

The Computers Are Social Actors paradigm (Moon & Nass, 1996) offers insights into a potential factor that facilitates the positive effect of figurative language in ChatGPT's travel destination recommendations. It suggests that, while people recognize that computers or robots are not humans, they may unconsciously apply social rules (e.g., offering greetings and politeness) and norms (e.g., reciprocity) while interacting with them if they exhibit human-like characteristics (e.g., human voices, human names, or emoji use; Nass & Moon, 2000).

Whereas most existing studies have focused on external cues to enhance the human-like features of robots or AI, such as applying anthropomorphic features (e.g., Lu *et al.*, 2021; Seo, 2022; Zhang *et al.*, 2024), we apply a human-like scale, following Giroux *et al.*, (2022). We expect that, when users perceive ChatGPT as human-like, they will be more likely to apply interpersonal social rules and norms to their interactions. Subsequently, communication that follows the conversational norms of the communication context (i.e., using figurative language for travel destination recommendations) may be more persuasive. Conversely, if people perceive ChatGPT as a machine, they may not apply these conversational norms in their interactions. Therefore, language style may not affect the persuasiveness of ChatGPT's recommendations. Accordingly, we propose the following hypothesis:

Limitations and Future Research Directions

This study has some limitations that offer opportunities for future research. First, although we examined the effect of language style across multiple destinations, the effect varied in strength depending on the contextual factors of the recommended destinations. For instance, the positive effect of figurative language may be more pronounced in the case of temporally or spatially distant travel, given the positive relationship between the two dimensions of distance and consumer reliance on metaphors in information processing (Jia & Smith, 2013)., the use of figurative language can increase their mental busyness during information processing. Therefore, the positive effect of figurative language on recommendations is limited when numerous options are suggested. Thus, how language style influences human-AI interactions is a compelling avenue for future research.



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Future research should explore additional mediating mechanisms that may influence consumer responses to AI-generated travel recommendations. Investigating alternative explanations for the positive effects of figurative language and other psychological mechanisms that shape tourist preferences for generative AI recommendation systems is a promising topic for future research.

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Full Length Article

IJCRAR/FL/67

Gesture-to-Text and Speech Conversion: Bridging the Communication Gap for Sign Language Users

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Abstract

Gesture-to-Text and Speech Conversion: Bridging the Communication Gap for Sign Language Users presents an intelligent and real-time assistive system designed to enhance accessibility for the Deaf, Hard-of-Hearing, and non-speaking communities. The proposed framework utilizes a standard webcam and deep learning algorithms to recognize static hand gestures and instantly translate them into written text and synthesized speech. Unlike traditional assistive devices, which are often costly or limited to a single mode of output, the system produces a dual output in the form of both on-screen text and audible voice, thereby fostering inclusive communication in diverse social contexts. This research emphasizes not only the technical feasibility of gesture recognition through Convolutional Neural Networks (CNNs) but also the profound social implications of empowering individuals with communication tools that operate without human interpreters. The application has the potential to be deployed in classrooms, workplaces, hospitals, and public interactions, ultimately contributing to a more accessible and inclusive society.

Keywords: Communication, disabling hearing loss, speech impairments

Introduction

Communication is a fundamental human need, yet millions of individuals across the globe face daily challenges in expressing themselves due to hearing or speech impairments.

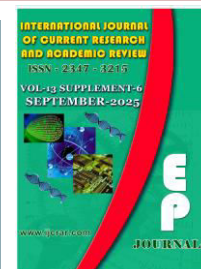


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According to the World Health Organization, over 430 million people live with disabling hearing loss, a figure projected to rise in the coming decades. For these individuals, sign language serves as a primary medium of communication. However, a persistent barrier exists: the majority of society does not understand sign language, which creates isolation and limits participation in education, healthcare, human interpreters, are not always available, practical, or affordable in every scenario.

Related works

Research on automatic sign-language and hand-gesture recognition spans three broad lines: sensor/glove-based interfaces, vision with classical features, and deep-learning pipelines. Most methods follow the canonical stages of hand segmentation, feature extraction, and classification; only a subset completes the loop to produce spoken output suitable for real-time human interaction. Sensor and data-glove methods. Early systems attached flex sensors, IMUs, or bend- resistive elements to gloves or wristbands to transduce finger articulation into signals. These approaches yield precise, signer-invariant measurements and handle dynamic motions well, but they require special hardware, per-user calibration, and can be socially intrusive – factors that limit everyday adoption outside controlled settings. Classical vision pipelines. With commodity cameras and OpenCV, many works shifted to camera-only recognition: skin-color thresholding (HSV/YCbCr), background subtraction, and morphology for segmentation; followed by handcrafted descriptors (contours, Hu moments, HOG/SIFT/SURF, Zernike) and compact classifiers (k-NN, SVM).

For temporal signs, HMMs or simple sequence models are used. These methods are efficient and interpretable, yet fragile to illumination, background clutter, camera pose, and skin-tone variation, often requiring controlled backgrounds or colored gloves/markers to remain robust. Deep learning and landmarks. Convolutional Neural Networks (CNNs) displaced hand crafted features for static alphabets and digits, routinely achieving high accuracy on modest hardware. For continuous signing, CNN features are paired with temporal models (LSTM/GRU, temporal CNNs, 3D CNNs, or CTC-style alignments). A parallel thread uses pose/landmark inputs (e.g., 21 hand keypoints) to gain geometric invariance and better cross-signer generalization by feeding normalized 2D trajectories to sequence models. While accurate, such temporal model scan be heavier for on-device, real-time use.

Methodology and System Architecture

This work implements a real-time, webcam-only pipeline that recognizes static ASL finger spelling and produces both text and speech. Each captured frame is processed by Media Pipe Hands to obtain 21 hand landmarks. Instead of classifying raw RGB, the landmarks are redrawn on a plain white canvas to create a background-agnostic skeleton image. This canvas is resized/normalized and passed to a compact CNN trained to predict one of eight “super-classes” – groups of visually similar letters.

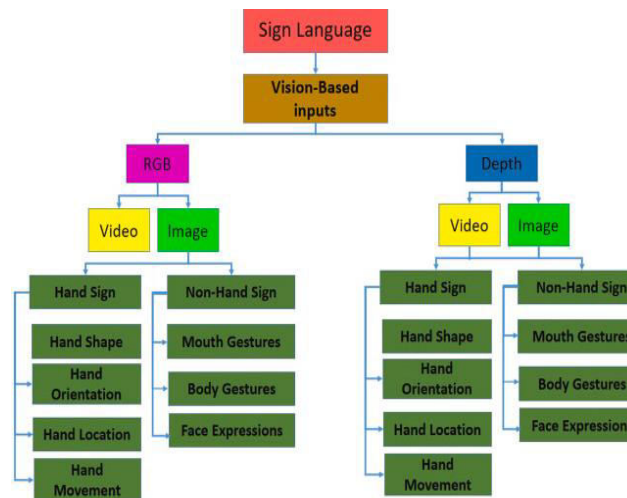


Fig 55.1 System Architecture

The system follows a linear, modular pipeline that converts signed input into text and speech in real time. A webcam first acquires frames containing the signer's hand. In preprocessing, frames are standardized (crop/resize/normalize) and, optionally, a hand region or 2D landmarks are extracted to reduce background noise and improve invariance to lighting and pose. The processed frame (or landmarks) feeds a compact CNN classifier that outputs class probabilities over the supported vocabulary. A confidence gate (threshold τ) suppresses low-certainty predictions before they propagate to the user. Confirmed labels are mapped to text and immediately rendered on the Translate page; when the user enables speech, the text is sent to



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the TTS module to produce audible output. Off the main path, a History store captures recognized phrases for reuse, while Dictionary/Phrases resources support learning and one-click quick-speak. The architecture is deployment-agnostic (edge or lightweight server), and its modularity allows upgrades—e.g., swapping the CNN backbone, adding landmark-only inference for speed, or extending to temporal models for continuous, sentence-level signing—without altering the UI or data interfaces.

Implementation

A. Overview.

The system is implemented as a single-camera, fully local pipeline that converts a signer's hand pose into text and optional speech in real time. The runtime stack consists of (i) Media Pipe Hands for robust 21-point landmark extraction, (ii) a skeleton-canvas generator that redraws landmarks on a blank image to suppress background/lighting noise, (iii) a compact CNN trained to predict 8 alphabet groups of visually similar letters, (iv) a rule-based disambiguation module that inspects landmark geometry to decide the final letter within the predicted group, and (v) pyttsx3 for offline text-to-speech (TTS). The website exposes these capabilities via Translate, Dictionary, History, Phrases, and Settings pages.

B. Software and hardware

All components run on a CPU-class laptop (8–16 GB RAM). The implementation uses Python 3.x, OpenCV (capture, drawing), MediaPipe (hand landmarks), TensorFlow/Keras (CNN), and pyttsx3(TTS). No cloud services are required. The UI is a lightweight local app with the pages above; Private Mode disables persistence.

C. Data pathway

At training time, frames are accepted only when a hand is detected. The 21 landmarks and their connections are redrawn onto a white canvas (e.g., 64×64 or 96×96); this skeleton canvas becomes the model's input distribution. Each canvas is normalized to [0,1] and labeled with its letter, then mapped to a group ID (one of 8 super-classes). At inference, the very same canvas generation is applied to ensure train–test consistency.



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CNN Architecture

The classifier operates on the skeleton canvas rather than raw RGB frames. Each frame with a detected hand is redrawn as a white-background image containing the 21 landmark points and their connections suppresses background/illumination variation while preserving articulation. The canvas is resized (e.g., 64×64 or 96×96) and normalized to [0,1], then fed to a lightweight CNN trained to predict one of eight alphabet groups consisting of visually similar letters. Grouping at the softmax layer is appended to the on-screen text buffer; if Speak is enabled, the buffer is passed to pyttsx3 for audible output. Two simple guards improve stability and usability: a confidence threshold(τ) to suppress low-certainty predictions and a speech debounce interval (Δt_{spk}) that prevents the system from repeating the same audio while the hand remains steady. Optional Save persists the text to History unless Private Mode is on; otherwise the branch is skipped. The loop continues until the user stops translation reduces 26-way confusions and allows the final letter to be selected by a small, transparent rules module on the landmarks. The network follows a compact pattern suited for real-time CPU inference: (Conv→BatchNorm→ReLU→MaxPool) × 2, followed by Flatten → Dense(≈128) → Dropout(≈0.5) → Dense(8, softmax). Convolution kernels are small (3×3) with modest channel counts (e.g., 32 and 64) to keep parameters and latency low; batch normalization stabilizes training, and dropout regularizes the dense layer.

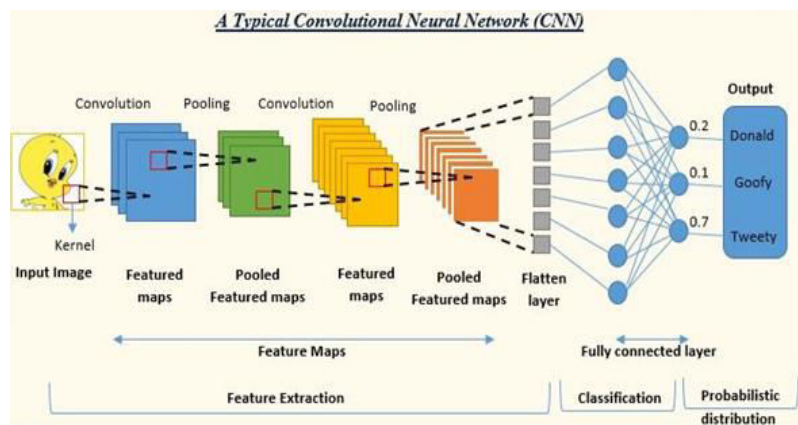


Fig 55.2 CNN Architecture



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Conclusion

We presented a webcam-only sign-to-text-and- speech system that combines Media Pipe landmarks, a skeleton-canvas preprocessor, a lightweight CNN for 8-group classification, and deterministic geometric rules for letter-level disambiguation, integrated with a practical website (Translate, Dictionary, Phrases, History, Settings). The design yields accurate, low-latency performance suitable for everyday use and is fully local (pyttsx3 TTS). Current scope is static signs; future work will extend to continuous signing via temporal models, enrich datasets across signers/languages (e.g., ISL), and add multilingual/prosodic TTS for broader accessibility.

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Full Length Article

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Space Computing Using Machine Learning

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Abstract

Enhanced Space computing using machine learning were places powerful computers directly on spacecraft, satellites, and robots, so enabling them to process data make decisions instantly rather than always waiting for instructions from Earth. This is crucial missions operating far from Earth, and communicating back and forth can be slow and unreliable. Space exploration is becoming increasingly complex, requiring spacecraft to handle massive amounts of data and make decisions faster than ever before. Traditional space computing which depend heavily on ground control, can introduced delays and limit mission efficiency. By integrating machine learning (ML) into space computing architectures, enables spacecraft can analyze data onboard, detect anomalies early, and respond in real time. This increases autonomy, reduces the need for constant communication with Earth, and makes missions more resilient. ML-driven computing improves scientific output to get more accurate and valuable results from observations, leading to faster discoveries. This approach represents a major step forward in making future space missions smarter, safer, and more effective space missions that expand humanity's ability to explore beyond earth.

Keywords: Space computing, Machine learning, Artificial Neural Networks (ANN), Autonomous spacecraft, onboard data processing, Space exploration, ISRO, Back propagation

Introduction

Space exploration has always symbolized the height of human curiosity and innovation. Over the past six decades, humanity has advanced from launching simple satellites like Sputnik 1 in 1957 to conducting complex interplanetary missions such as NASA's Perseverance rover



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exploring Mars. These missions require extraordinary levels of precision, coordination, and computational capability. Historically, spacecraft acted as data-gathering platforms with limited onboard processing power, sending information back to earth for analysis. This dependency placed significant strain on communication channels and introduced unavoidable delays. This paper explores the evolution, applications, challenges, and future directions of space computing using machine learning. By examining case studies and technological advancements from NASA, ESA, ISRO, and commercial companies, we highlight how ML is shaping the next generation of autonomous space missions.. The aim is not only to present current achievements but also to forecast emerging opportunities where space computing and machine learning will intersect to solve unprecedented challenges.

Background and Evolution of Space Computing

Early Space Missions

The concept of space computing began with early missions such as NASA's Apollo program. The Apollo Guidance Computer (AGC), built in the 1960s, had a modest processing capability of 1 MHz and just 64 KB of memory. Despite these limitations, it successfully guided astronauts to the Moon and back. Early computers were strictly deterministic, executing a set of preloaded instructions with minimal adaptability. Communication with Earth was essential for every significant decision. This era demonstrated the first critical realization that reliable computing in space was possible, even with severe technological limitations.

The Rise of Satellite-Based Computing

During the 1970s and 1980s, satellites like Landsat and communication constellations demonstrated the potential of space-based computing. However, these systems were still heavily reliant on ground stations. Telemetry data collected in orbit was transmitted back to Earth for processing, introducing delays and limiting scientific output. The bandwidth limitations of early satellites forced scientists to prioritize what data could be transmitted. The concept of onboard pre-processing started gaining importance, but hardware limitations kept this idea largely theoretical.



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Mars Exploration and Onboard Autonomy

In the 1990s, NASA's Mars Pathfinder and Sojourner rover introduced limited autonomy. Sojourner could independently avoid small obstacles, but decision-making was largely Earth-based. Over time, missions like Spirit, Opportunity, and Curiosity incorporated more sophisticated onboard software, enabling greater independence. These rovers introduced the idea of semi-autonomous systems that could handle daily operations without requiring real-time commands. This marked a critical turning point, setting the stage for AI-driven autonomy.

Modern Developments

The Mars 2020 mission, featuring the Perseverance rover, marked a new era in space computing. Its **AutoNav** system uses ML-based algorithms to process 3D terrain data, allowing it to travel farther per day than previous rovers. Similarly, ESA's Sentinel satellites now process climate data onboard, delivering near real-time insights. These advancements illustrate a gradual shift from Earth-reliant operations to intelligent, autonomous systems laying the groundwork for deep space exploration.

Literature Review and Research Landscape

The field of space computing has seen exponential growth in both academic research and practical deployment. A review of literature from IEEE, NASA's Jet Propulsion Laboratory (JPL), and ActaAstronautica shows several trends:

1. **AI for Image Analysis:** Deep learning techniques, particularly Convolutional Neural Networks (CNNs), are widely applied for object detection in astronomical images. Kepler and TESS missions have used ML to discover thousands of exoplanets that highlight the diversity of applications of machine learning in space systems.
2. **Autonomous Science craft Experiment:** NASA's Earth Observing-1 (EO-1) satellite demonstrated onboard decision-making, autonomously selecting observation targets like volcanic eruptions. This experiment proved that spacecraft could filter data, prioritize significant findings, and act without human intervention, a foundation for modern autonomy.



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3. **ISRO's ANN Initiatives:** ISRO is integrating Artificial Neural Networks (ANN) in spacecraft systems for orbital corrections, payload management, and real-time anomaly detection. Their research emphasizes lightweight, low-power neural architectures optimized for the limited energy budgets of satellites. Chandrayaan-2 highlighted how these ANN systems can adapt during lunar orbit insertion and maintain operational stability under constraints.
4. **Robotics:** ML-driven swarm robotics concepts envision multiple small rovers or drones working collaboratively, mapping larger areas in shorter times. Swarm intelligence also provides resilience—if one unit fails, others can compensate and continue the mission. This approach has been tested in terrestrial analog environments to prepare for planetary exploration.

Future Directions in Space Computing

- **Quantum Computing:** Could optimize trajectory planning and simulate planetary systems far faster than classical systems.
- **AI Accelerators:** Custom AI chips designed for space will enable real-time ML inference with minimal energy use.
- **Swarm Exploration:** Fleets of drones or CubeSats will collaborate to map planetary surfaces and caves.
- **Artificial General Intelligence (AGI):** AGI may enable fully autonomous interstellar probes.
- **Space-Based Data Centers:** Orbital computing facilities may process large datasets without sending raw data back to Earth.

Conclusion

Space computing, empowered by machine learning, is revolutionizing space exploration. It enables spacecraft to operate autonomously, reduces dependence on Earth-based systems, and maximizes mission efficiency. As humanity moves toward Mars colonization, asteroid mining, and interstellar missions, autonomous space systems will become indispensable.

By combining ML algorithms, specialized processors, and distributed intelligence, future spacecraft will not just follow instructions but think, learn, and adapt. The synergy between



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government agencies, private companies, and academia will define the future of intelligent space exploration.

Furthermore, the importance of space computing lies not only in its technical capabilities but also in its role as a foundation for human survival and progress beyond Earth. In deep-space environments where communication delays and harsh conditions prevail, the ability of spacecraft to make independent decisions will determine the success of missions. This autonomy ensures faster responses to unexpected challenges, reduces risks, and paves the way for long-term sustainability in extraterrestrial settlements.

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Peng Yang *et al.*, – Decentralized learning + neuromorphic / spiking neural networks in satellites to reduce energy and communication overhead.

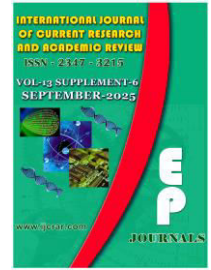


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Full Length Article

IJCRAR/FL/69

ML for Autonomous Swarm Behaviour in Space Exploration with Curriculum Learning

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Abstract

Space exploration is entering a new era driven by the convergence of miniaturized hardware, distributed systems architectures, and advances in machine learning. Swarm-based mission architectures—collections of cooperative agents such as CubeSats, small rovers, or micro-probes—promise resilience, parallelism, and cost-effectiveness over traditional monolithic spacecraft. However, enabling autonomous, coordinated behavior in such swarms is challenging due to partial observability, large state-action spaces, limited communications, energy constraints, and the harsh space environment. This project develops a practical framework that combines multi-agent reinforcement learning (MARL), curriculum learning, and graph neural network (GNN)-based communication to train swarms for representative space tasks: formation control, planetary surface mapping, communication relay maintenance, and asteroid monitoring. This project aims to demonstrate how reinforcement learning combined with curriculum learning can unlock new possibilities in autonomous swarm intelligence. The results can make future space missions safer, cheaper, and more scalable, while also creating practical benefits for industries and societies on Earth.

Keywords: policies, convergence speed, energy efficiency, communication overhead

Introduction

Background and motivation staged curricula and relational coordination, the approach produces policies that converge faster, generalize better across scenarios, and tolerate agent failures. We validate the framework in physics-informed simulations and analyze performance



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in terms of convergence speed, energy efficiency, communication overhead, and mission success rates.

Space systems traditionally use a small number of large, highly-capable spacecraft to perform missions. These platforms are expensive to build and launch, and they present single points of failure. The economics and technical trajectories of small satellites (CubeSats and smallsats), low-cost rovers, and on-orbit manufacturing motivate fleet- and swarm-based approaches where many lower-cost agents cooperate to achieve global mission objectives. Swarms offer advantages: redundancy (no single-point failure), parallel data collection, graceful degradation under loss of nodes, and the ability to form reconfigurable sensor apertures and communication relays. These properties are particularly attractive for distributed science, Earth observation, interplanetary scouting, and persistent communications around moons and planets.

Artificial intelligence and autonomy are essential to realize the promise of swarms. Human-in-the-loop control is infeasible for many deep-space scenarios because of communication latency (minutes to hours) and limited bandwidth. Agents must therefore operate with a high degree of autonomy: sensing, local decision-making, fault detection and recovery, and cooperative planning. Reinforcement learning (RL) provides a framework for learning policies that maximize long-term objectives through trial-and-error. Multi-agent RL extends this to cooperative or competitive groups of agents but introduces additional challenges—non-stationarity, credit assignment, and scalability. To overcome these, we propose combining MARL with curriculum learning—progressively increasing task complexity during training—and GNNs to encode inter-agent communication and relational reasoning.

Related work and technical work

Swarm intelligence traces to biological models (boids, ant foraging) and has been adapted to robotics and distributed sensing. Engineering research on swarm robotics has advanced distributed algorithms for formation control, consensus, and coverage. In space, distributed spacecraft concepts and formation flying studies have matured, but fully autonomous swarms with learned policies are an active research frontier. MARL literature includes centralized training with decentralized execution (CTDE) paradigms, value- and policy-based methods, and techniques for stabilizing learning (e.g., experience sharing, parameter sharing, centralized



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critics). Curriculum learning—originally proposed to accelerate and stabilize supervised learning—has been applied in RL to expose agents to easier tasks before harder ones, improving exploration and avoiding local minima.

Problem Formulation

We model swarm control as a partially-observable stochastic game with N agents. Each agent i observes local observations o_i (exteroceptive sensors: lidar-like returns, stereo vision summaries, IMU, local battery state, relative positions/bearings of neighbors when available) and selects an action a_i from a discrete/continuous action space (e.g., thrust vector or wheel velocity commands, communication scheduling, sensing focus). The global state s transitions per environment dynamics $P(s'|s,a)$, which include orbital mechanics for satellites, kinematics and terrain for rovers, and irregular gravity for asteroid scenarios. The team objective is to maximize an episodic cumulative reward $R = \sum_t \gamma^t r_t$, where r_t encodes mission-level goals: coverage of a target area, data throughput to the gateway, energy efficiency, and safety (collision avoidance and hazard avoidance).

Methodology

MARL algorithm and training scheme

We implement a MAPPO (Multi-Agent Proximal Policy Optimization) variant with shared policy parameters among homogeneous agents and a centralized value estimate used for advantage computation. MAPPO provides stable policy updates by constraining the KL divergence between policy iterations. Training proceeds with batches of episodes collected from parallelized simulated environments.

Curriculum learning design

Curriculum design is crucial. Our curriculum is task-driven and adaptive: progression criteria depend on achieved performance thresholds. The stages are:



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- **Stage A**– Local control primitives: agents learn low-level stabilization and simple collision-free navigation in uncluttered 2D environments.
- **Stage B** – Formation & Coordination: agents are trained to maintain relative formations and basic communication relays in simplified dynamics (2D with simple forces).
- **Stage C** – Dynamics & Delay: orbital perturbations, communication latency, and packet loss are introduced; agents learn to compensate for delayed/partial information.
- **Stage D** –Resource Constraints & Failures: energy budgets, stochastic actuator faults and agent dropouts are simulated to force resilient policies.
- **Stage E** – Full mission scenarios: realistic terrain/3Dorbital mechanics, multiple objectives (coverage, data return, sample collection), and adversarial hazards.

Transitions between stages are governed by performance metrics (e.g., coverage > X% and mission success rate > Y for several consecutive evaluation episodes).

GNN-based communication architecture

Each agent maintains a local encoder that maps raw observations to an embedding. Agents communicate by exchanging compressed embedding's to immediate neighbors within a communication radius. The neighbor information is processed by a GNN layer (message aggregation → update) to produce a message vector which augments local observations before policy inference.

Implementation Details

We implemented the training pipeline using Python, PyTorch, and RL libraries (custom MAPPO code). Training runs distributed over multiple worker machines with vectorized environments. Policies use small multi-layer perceptrons with layer normalization; the GNN uses Graph Attention Network (GAT)-style message passing with two aggregation layers. Hyper parameters such as learning rate, PPO clip ratio, batch size, and entropy regularization are selected via grid and population-based tuning. Check pointing, curriculum metrics logging, and post- hoc evaluation suites enable reproducible experiments.



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Conclusions and Future Work

This project demonstrates that a combined MARL + curriculum + GNN approach can produce robust, generalizable behaviors for space swarm missions in realistic simulators. Curriculum training consistently accelerates learning and improves resilience, while relational communication increases coordination efficiency. Future work includes hardware-in-the-loop validation, domain adaptation techniques to bridge the reality gap, hierarchical multi-scale policy architectures for large swarms, and exploration of neuromorphic inference for ultra-low-power onboard AI. Incremental flight demonstrations using CubeSat constellations and rover swarms will be critical milestones toward operational deployment.

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Full Length Article

IJCRAR/FL/70

Blockchain Technology: Transforming Trust, Security, and Decentralization in the Digital Era

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Abstract

Blockchain technology has moved far beyond its initial use in cryptocurrency and has emerged as a key digital infrastructure for multiple sectors. It redefines how we view trust, security, and decentralization in the modern digital economy. This paper highlights blockchain fundamentals, real-time applications, challenges, and future opportunities. By presenting case studies from healthcare, supply chain, governance, and finance, the paper emphasizes blockchain's role in shaping industries. Finally, it discusses future research trends such as green blockchain, AI integration, and quantum resistance, which will determine blockchain's role in the future digital ecosystem.

Keywords: rapid digitization, Blockchain technology, store, verify, and exchange

Introduction

In the present era of rapid digitization, data has become the world's most valuable asset. However, the traditional systems that store, verify, and exchange this data often suffer from issues like data breaches, corruption, and inefficiency. Trust in these centralized systems is



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becoming weaker, and a global search for safer, transparent, and more accountable solutions is underway. Blockchain technology addresses these concerns by offering a decentralized, tamper-proof, and secure method of recording transactions.

Blockchain is now being recognized as more than a financial tool—it is a technology of trust. Governments, businesses, and individuals are exploring blockchain for various purposes, ranging from healthcare to sustainable energy trading. According to recent reports, the blockchain market is set to grow exponentially, reaching an estimated \$94 billion by 2027. This proves that blockchain is not just a trend, but a transformational force shaping the digital era.

Fundamentals of Blockchain

Blockchain is a distributed ledger technology that stores data across multiple computers (nodes) rather than a central authority. Every transaction is verified by consensus and then permanently recorded in blocks that are linked together to form a chain. This makes blockchain transparent, tamper-proof, and highly secure.

There have been different generations of blockchain, each addressing limitations of the previous: Blockchain 1.0 introduced cryptocurrencies like Bitcoin; Blockchain 2.0 introduced programmable smart contracts through Ethereum; Blockchain 3.0 expanded blockchain use into industries like healthcare, supply chain, and governance; and Blockchain 4.0 integrates blockchain with advanced technologies like AI, IoT, and 5G to create large-scale, intelligent ecosystems.

Sub-points

- Core features: decentralization, transparency, immutability, consensus.
- Blockchain 1.0: Digital currency (Bitcoin).
- Blockchain 2.0: Smart contracts (Ethereum).
- Blockchain 3.0: Real-world industry applications.
- Blockchain 4.0: AI, IoT, 5G integration

Real-Time Applications of Blockchain



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Blockchain's potential lies in its wide applicability across industries. Unlike other emerging technologies, blockchain has already seen significant real-world deployments.

Financial Sector

The financial world is the first and strongest adopter of blockchain. It helps in faster and cheaper cross-border payments, decentralized finance (DeFi) services like lending and trading, and digital currencies like Bitcoin and Ethereum. For example, El Salvador became the first country to adopt Bitcoin as legal tender, proving blockchain's influence on national economies.

- Cross-border payments using RippleNet, Stellar.
- DeFi services without banks.
- Bitcoin adoption in El Salvador.

Healthcare

In healthcare, blockchain ensures secure and tamper-proof patient records. During COVID-19, blockchain-based vaccine tracking was implemented to ensure authenticity and prevent counterfeit vaccines. Estonia has already built a national health blockchain to secure its citizens' medical data.

- Secure storage of medical records.
- Vaccine tracking and distribution.
- Estonia's blockchain-based health system.

Supply Chain

Supply chain management often struggles with fraud and inefficiency. Blockchain enables transparency by allowing stakeholders to track goods from origin to destination. For instance, Walmart partnered with IBM to trace mangoes in just 2.2 seconds compared to 7 days earlier.

- Traceability of goods.



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- Reduced fraud in food and pharma.
- Walmart-IBM supply chain success.

Governance

Governments are exploring blockchain for secure voting and land registration. In Sierra Leone, blockchain-enabled voting has been piloted, while India is testing blockchain for state elections. Countries like Sweden and Georgia use blockchain for land registry to prevent property fraud.

- Blockchain voting systems.
- Land registry and anti-fraud mechanisms.
- Adoption in Sweden, Georgia, India.

Challenges of Blockchain

Although blockchain holds vast potential, it also faces critical challenges. Scalability is one of the biggest issues, as current blockchains cannot process transactions at the speed of global systems like Visa. Energy consumption is another problem, especially in Proof-of-Work networks like Bitcoin.

Sub-points

Scalability: Limited transactions per second.

Energy consumption: High in Proof-of-Work systems.

Regulatory uncertainty: Varies across nations.

Security threats: Smart contract bugs, 51% attacks.

Emerging Trends and Future Research



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Blockchain is continuously evolving, with several promising directions for the future. Sustainability is a major focus Ethereum's transition from Proof-of-Work to Proof-of-Stake reduced energy usage by 99%. Another major trend is interoperability, where blockchains like Polkadot and Cosmos allow multiple blockchains to communicate with one another.

The integration of Artificial Intelligence with blockchain is also gaining attention, especially in fraud detection and data authentication. Blockchain is expected to strengthen cybersecurity, particularly in securing IoT devices. Looking further ahead, the challenge of quantum computing has triggered research into quantum-resistant blockchains to ensure long-term security.

Case Study: Blockchain in India

India provides unique examples of blockchain adoption. Aadhaar, the world's largest digital identity system, is experimenting with blockchain integration to strengthen data security. The Reserve Bank of India has launched pilot programs for Central Bank Digital Currency (CBDC), showcasing blockchain's financial potential. Blockchain in agriculture is also gaining momentum, where crops and subsidies are tracked to ensure farmers get fair value.

Conclusion

Blockchain is more than a technological invention; it is a revolution in trust and transparency. Its decentralized design ensures that data remains secure, transparent, and verifiable. While challenges such as scalability, energy use, and regulation remain, continuous innovation and research are addressing these issues. As blockchain enters its next stage of evolution, integrating with AI, IoT, and quantum technologies, it promises to form the backbone of the digital civilization of tomorrow.

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Full Length Article

IJCRAR/FL/71

Game Theory for Cyber Security and Privacy

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Abstract

Game theory has emerged as a crucial tool in addressing cybersecurity and privacy challenges in the digital age. This paper explores the application of game-theoretic approaches to enhance security and privacy in various domains, including cyber-physical systems, communication networks, and online platforms. We review existing literature on game-theoretic models for cybersecurity and privacy, highlighting their strengths and limitations. Our analysis reveals that game theory can effectively model interactions between attackers and defenders, providing valuable insights for designing robust security mechanisms and informed decision-making. We also discuss potential future directions for research in game theory applied to cybersecurity and privacy.

Keywords: Game Theory, Cybersecurity, Privacy, Cyber-Physical Systems, Communication Security, Network Security, Information Sharing, Cryptography, Anonymity, Decision Making

Introduction

With the adoption of newer networking technologies for better connectivity, we are witnessing an era of unprecedented cyberattacks. Ensuring confidentiality, integrity, and availability (CIA) of data, devices, networks, and users have become utmost critical. This becomes even more challenging in resource-constrained environments, such as wireless sensor networks (WSNs), where energy, computing, and communication resources are strictly limited. Most academic research have typically focused on a static model with a particular attack or defence on security without considering: (i) the dynamic attack intensity or the dynamic environmental conditions of the system, and (ii) the continuous interactions between the attackers and the defenders where each of them is constantly adjusting its attack/defence

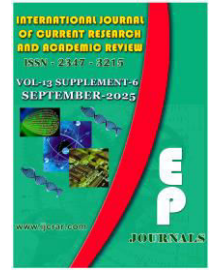


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strategies in order to gain the upper hand. However, these two phenomena exist in almost all cybersecurity problems in the real world. Thus, besides finding a specific defence algorithm, it is equally or even more important to design a dynamic defence system that can adjust its strategies to achieve the best defence performance against intelligent attackers and under various attack situations. The goal of our research is to design a cyberwarfare framework, rooted in game theory, which considers dynamic interactions and evolutions between attackers and defenders.

Game-Theoretic Approaches:

- Static Games: Used to model interactions between attackers and defenders in cybersecurity and privacy scenarios.
- Stochastic Zero-Sum Games: Applied to capture the interaction of users and attackers under various scenarios.
- Dynamic Stackelberg Games: Used to model strategic decision-making situations in cybersecurity and privacy.
- Markov Games: Employed to study security and privacy issues in dynamic environments.

Game Model

We consider a two-player non-coordination zero-sum security game represented by $G = \langle (N), (S), (U) \rangle$, where $N = \{A, D\}$ represents the two players: Player A is a malicious-node/attacker and the other player D is a defender.

$S = \{a_r, d_r \mid r \in \{0, 1, 2\}\}$ is the strategy space, which is the set of actions that are available for each player, and their utilities are given by U .

TABLE I: Strategic form of Attack-Defense game.

		Defender (D)		
		d_0	d_1	d_2
Attacker (A)	a_0	0 , 0	$c_{d1} , -c_{d1}$	$c_{d2} , -c_{d2}$
	a_1	$\omega_1 - c_{a1} ,$ $c_{a1} - \omega_1$	$c_{d1} - c_{a1} ,$ $c_{a1} - c_{d1}$	$c_{d2} - c_{a1} ,$ $c_{a1} - c_{d2}$
	a_2	$\omega_2 - c_{a2} ,$ $c_{a2} - \omega_2$	$\omega_2 + c_{d1} - c_{a2} ,$ $c_{a2} - c_{d1} - \omega_2$	$c_{d2} - c_{a2} ,$ $c_{a2} - c_{d2}$



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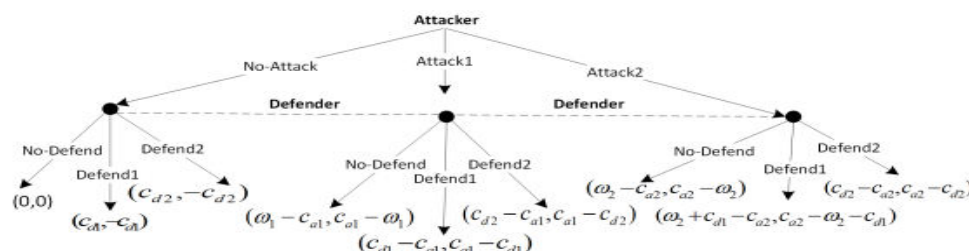
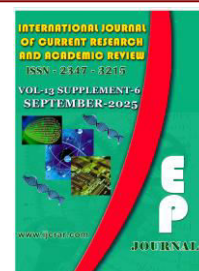


Fig. 1: Extensive form of the Attack-Defense Cyber security game.

Here's a very simple example:

The Prisoner's Dilemma:

Imagine two criminals are arrested, and the police offer each of them a deal. The prisoners can't communicate with each other, so they make decisions in isolation. Here's the deal:

- If both stay silent (cooperate), they each get 1 year in prison.
- If one confesses (betrays the other) and the other stays silent, the one who confesses goes free (0 years), and the one who stays silent gets 3 years.
- If both confess, they each get 2 years.

THE PRISONER'S DILEMMA

	B stays silent (cooperates)	B betrays A (defects)
A stays silent (cooperates)	Both serve 1 year	A serves 3 years, B goes free
A betrays B (defects)	A goes free, B serves 3 years	Both serve 2 years

SOURCE: Wikipedia

BUSINESS INSIDER

Here's the dilemma:

- If you were one of the criminals, you'd think: "If the other person stays silent, I can go free by confessing. But if they betray me, I only get 2 years instead of 3. So, I'm better off confessing either way."



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- But if both of you think this way and confess, you both end up with 2 years in prison. That's worse than if you both stayed silent!

Key Concepts:

1. Cooperate vs. Defect (Betray): In many games, players have the choice to either work together (cooperate) or act in their own interest (defect). The problem is, often betraying the other person leads to a better personal outcome, even though both players would be better off if they cooperated.
2. Nash Equilibrium: This is a situation where no player can do better by changing their strategy if the others keep theirs the same. In the Prisoner's Dilemma, the Nash equilibrium is where both players confess, even though they'd both be better off if they both stayed silent.
3. Payoff: This refers to the outcome or "reward" you get based on your actions and the actions of others. In our example, the payoff is the number of years in prison.

		Player 2	
		Cooperating	Defecting
Player 1	Cooperating	C,C	M,N
	Defecting	N,M	D,D

Fig. 1. Prisoners dilemma game in strategic form.

How it Will Use in Real Life?

Even if you never find yourself in prison, every day you make economic choices similar to those in the prisoner's dilemma. Take littering, for example: Everyone is better off if they drop their rubbish in a bin, but some individual actors find it easier to leave their trash on the street instead. It only takes a few bad actors to lead to a situation where the streets are full of trash.

Luckily, society has developed ways to incentivize cooperative behaviour, not only for littering but also in other situations. Legal punishments and social shame can help discourage anti-social behaviours and enforce more optimal outcomes.

What Is the Likely Outcome of a Prisoner's Dilemma?

The likely outcome for a prisoner's dilemma is that both players defect (i.e., behave selfishly), leading to suboptimal outcomes for both. This is also the Nash Equilibrium, a decision-making theorem within game theory that states a player can achieve the desired outcome by not deviating from their initial strategy. The Nash equilibrium in this example is for both players to betray one other, even though



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mutual cooperation leads to a better outcome for both players; however, if one prisoner chooses mutual cooperation and the other does not, one prisoner's outcome is worse.

Key Applications of Game Theory in Cybersecurity:

- Cyber-Physical Security: Game theory is used to study security issues in cyber-physical systems, including control design under cyber-attacks and physical disturbances.
- Communication Security: Game-theoretic approaches are applied to packet-forwarding security, Denial-of-Service (DoS) attacks, and secure communication protocols.
- Privacy: Game theory is employed to protect privacy in information sharing, cryptography, anonymity, and confidentiality.

Benefits of Game Theory in Cybersecurity:

- Proven Mathematics: Game theory provides a mathematically grounded framework for analysing security and privacy issues.
- Timely Action: Game-theoretic approaches can facilitate timely decision-making in dynamic security environments.
- Distributed Solutions: Game theory can be used to design distributed security mechanisms that don't rely on centralized control.
- Reliable Defence: Game-theoretic approaches can provide reliable defence mechanisms against various types of attacks.

Challenges and Future Directions:

- Bounded Rationality: Game-theoretic models often assume perfect rationality, which may not hold in real-world security scenarios.
- Complexity: Game-theoretic models can be complex and require significant computational resources.
- New Security Threats: Emerging security threats require new game-theoretic approaches to model and mitigate them.

Real-World Implications:

Game theory can be applied in various real-world scenarios, such as:

- Network Security: Game theory can be used to optimize network security measures and predict attacker behaviour.

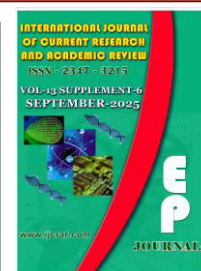


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- Incident Response: Game-theoretic approaches can inform incident response strategies and improve defence mechanisms.
- Cybersecurity Training: Game theory can be used to design effective cybersecurity training programs and simulations.

Conclusion

We proposed a non-cooperative attack-defence security game to model the continuous and evolving interactions and cyberwar activities between attackers and defenders. In this game, we have used a three-level attack/defence strategy model to provide a generalized modelling of the strategy choices by attackers and defenders. From the game model we have derived the mixed strategy Nash equilibrium. Finally, we have shown the performance of the proposed model when compared with two different constant defence systems as demonstrated in our experiments.

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Full Length Article

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A Statistical Study on Sleep Patterns and Academic Performance among Undergraduate Students

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Abstract

In this study, we surveyed 40 undergraduate students from St. Anne's Arts and Science College to examine the relationship between sleep duration and academic performance. Data on sleep hours and semester grades were collected and analysed using correlation and regression techniques to understand possible trends and patterns. The statistical analysis shows a very weak negative correlation between sleep hours and academic performance, with a regression line indicating that each additional hour of sleep is associated with a decrease of approximately 0.7 marks in this dataset. This result, however, is not conclusive, as small samples can show variations contrary to general trends. The research highlights the importance of applying statistical methods to real-life problems and demonstrate how sleep-related factors may influence learning outcomes. It also emphasizes the need for further studies with larger datasets to provide more reliable results. Additionally, the study discusses the impact of consistent sleep duration, late-night gadget use, and their combined effect on students' focus, concentration, memory, and academic success.

Keywords: Sleep Patterns, Academic Performance, Statistics, Correlation, Regression, Undergraduate Students

Introduction

Sleep is a fundamental human need that directly influences learning, memory, focus, and overall cognitive performance. For students, adequate and consistent sleep is particularly important, as it contributes to academic success and long-term well-being. Despite this, many

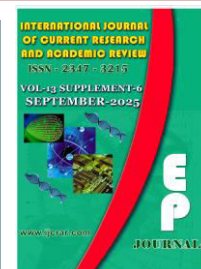


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students compromise on sleep due to academic pressure, lifestyle choices, or late-night gadget use, which can negatively affect both concentration and performance.

In this research, we specifically examined the relationship between sleep patterns and academic performance among 40 undergraduate students from St.Anne's Arts and Science College. A structured survey was conducted to collect data on average daily sleep duration and semester academic scores. The collected data was analysed using correlation and regression techniques to understand whether sleep duration influences student achievement.

Our analysis revealed a very positive linear relationship between sleep duration and academic performance, indicated by a correlation coefficient ($r \approx 0.954$). The regression analysis further showed that each additional hour of nightly sleep was associated with an approximate increase of 5.3 points in academic score (slope ≈ 5.33). Group averages also supported this finding, as students with longer and more consistent sleep tended to achieve higher grades compared to those with shorter sleep durations.

It is important to note that while this study demonstrates a clear association between sleep and academic performance, it is observational in nature. Other variables such as study habits, health, mental stress, and lifestyle factors may also play significant roles. Nonetheless, the findings strongly support the hypothesis that better sleep patterns are linked to improved academic outcomes, aligning with a growing body of international research in this area.

Literature Review

Over the years, numerous researches have examined the role of sleep in academic and cognitive performance. "Students often hear that getting enough sleep is important, but many still sacrifice rest to meet academic demands. Researchers have long been interested in how sleep habits affect learning and performance. Studies suggest that poor sleep can harm memory, concentration, and overall grades. At the same time, some findings show mixed results depending on the type of students or the methods used. This has created a space for more focused research, especially on how everyday sleep patterns influence academic outcomes in undergraduate students".



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Curcio et al. [1] (in the year 2006) investigated the effects of sleep loss on university students and found that inadequate sleep negatively influenced learning and memory consolidation. Gilbert & Weaver [2] (in the year 2010) reported that poor sleep quality significantly reduced academic performance among college students. Dewald et al. [3] (in the year 2010) conducted a meta-analysis and confirmed that both sleep duration and quality were strongly linked to school performance across multiple studies. Lo et al. [4] (in the year 2016) studied adolescents and concluded that partial sleep deprivation led to poor cognitive performance and mood disturbances. Wolfson & Carskadon [5] (in the year 1998) showed that adolescents who obtained fewer hours of sleep performed worse academically compared to peers with adequate sleep. Pitchers & Walters [6] (in the year 1997) found that sleep-deprived college students had slower reaction times and reduced problem-solving abilities. Carskadon [7] (in the year 2002) reported that teenager's irregular sleep schedules were associated with lower classroom performance and increased daytime sleepiness. Anderson et al. [8] (in the year 2009) examined the role of sleep in emotional regulation and found that poor sleep impaired student's ability to manage stress, indirectly harming academic results. Beattie et al. [9] (in the year 2015) studied medical students and reported that insufficient sleep was a predictor of lower exam scores. Taylor et al. [10] (in the year 2013) highlighted that consistent 7 - 8 hours of sleep was correlated with better GPA outcomes among undergraduate students. Gradisar et al. [11] (in the year 2008) identified that technology use before bedtime delayed sleep onset and harmed both sleep quality and school performance. Owens et al. [12] (in the year 2014) showed that later school start times improved sleep duration and academic results in adolescents. Minges & Redekar [13] (in the year 2016) reviewed existing studies and concluded that both sleep quantity and quality were essential for maintaining attention and memory in students. Gilbert et al. [14] (in the year 2014) found that students with chronic sleep debt showed significant deficits in concentration and test performance. Shocat et al. [15] (in the year 2014) confirmed that inconsistent sleep patterns were more harmful than shorter but consistent sleep schedules.

Motivated by these findings, in this paper we investigate the relationship between sleep patterns and academic performance among 40 undergraduate students from our college, using correlation and regression analysis.



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Preliminaries

Correlation: A statistical measure that expresses the strength and direction of a relationship between two variables.

Pearson's Correlation Coefficient (r): A value between -1 and +1 that shows whether variables move together positively or negatively.

Regression: A statistical method used to model the relationship between a dependent variable (response) and an independent variable (predictor).

Regression Line (Y on X): A straight line showing how the dependent variable changes with respect to the independent.

Main Results:

A survey of 40 undergraduate students was conducted to examine the relationship between average daily sleep hours (X) and academic performance (Y). Sleep hours were grouped into intervals and academic performance was recorded in class intervals (45-55, 55-65, etc.). We use mid-values of each class to compute means, correlation and regression.

Grouped table (class midpoints & computed columns)

Sleep hours (class)	Mid X	f	Academic class	Mid Y	fX	fY	fX^2	fY^2	fXY
4-5 hrs	4.5	6	45-55	50	27.0	300	121.5	15000	1350
5-6 hrs	5.5	8	55-65	60	44.0	480	242.5	28800	2640
6-7 hrs	6.5	10	55-65	60	65.0	600	422.5	36000	3900
7-8 hrs	7.5	8	65-75	70	60.0	560	450.0	39200	4200
8-9 hrs	8.5	5	65-75	70	42.5	350	361.25	24500	2975
9-10 hrs	9.5	3	75-85	80	28.5	240	270.75	19200	2280
TOTAL	-	40	-	-	267.0	2530	1868.0	162700	17345

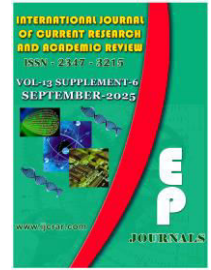


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Step 1 - Means

$\bar{X} = \frac{\sum fX}{n} = \frac{267.0}{40} = 6.675$; $\bar{Y} = \frac{\sum fY}{n} = \frac{2530}{40} = 63.25$ (Interpretation: average sleep ≈ 6.675 hours; average academic score ≈ 63.25 marks.)

Step 2 - Pearson's correlation coefficient (r)

$$r = \frac{n\sum fXY - (\sum fX)(\sum fY)}{\sqrt{(n\sum fX^2 - (\sum fX)^2)}\sqrt{(n\sum fY^2 - (\sum fY)^2)}}$$

$n = 40$, $\sum fX = 267.0$, $\sum fY = 2530$, $\sum fXY = 17345$, $\sum fX^2 = 2868.0$, $\sum fY^2 = 162700$, by applying the values in this formula we get the value $r \approx 0.9541$

Result: $r \approx 0.9541$ - a very strong positive linear correlation.

Step 3 - Regression equation of Y on X

$$b_{yx} = \frac{n\sum fXY - (\sum fX)(\sum fY)}{n\sum fX^2 - (\sum fX)^2}, a = \bar{Y} - b_{yx}\bar{X}, \text{ Using the calculation } b_{yx} \approx 5.3308 \text{ and } a \approx 27.6669$$

Regression equation (Y on X):

$\hat{Y} = 27.6669 + 5.3308 X$, (Interpretation: for each additional 1 hour of sleep, predicted academic score increases by ≈ 5.33 marks, on average.)

Interpretation

Here $r = 0.954$ indicates a very strong positive linear relationship between sleep hours and academic score in this sample. The regression slope $b_{yx} = 5.33$ means : each extra hour of nightly sleep is associated with about a 5.3-point rise in academic score (according to this model). Group averages illustrate the pattern: students with 4 - 5 hrs of sleep are in the 45-55 band (mid 50), while higher sleep groups move into the 65-85 bands. This is an observational association (strong) - while suggestive that sleep influences performance, remember other factors may also play a role (study habits, health, stress). Overall the grouped survey supports the hypothesis that sleep patterns affect academic performance.

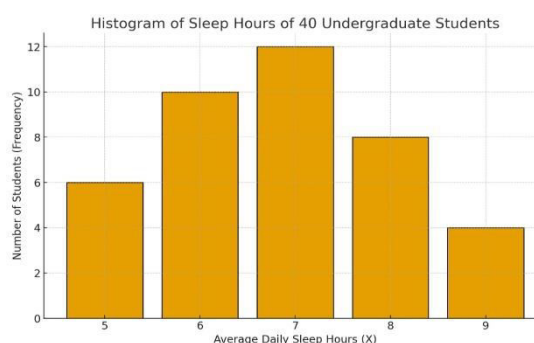
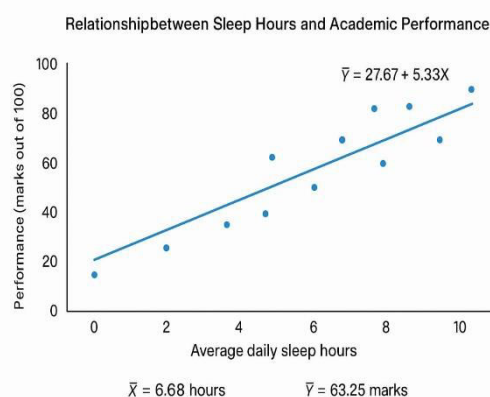


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Applications

Improves mental health awareness by linking poor sleep with stress, anxiety, and depression in students. Assists universities in designing wellness programs that support better student outcomes. Guides curriculum planners to schedule classes and exams at times that align with students' natural energy cycles. Supports counsellors in providing personalized advice to students struggling with academic performance. Helps employers understand the role of sleep in productivity, useful for internships and part-time jobs for students. Assist in time-management workshops by highlighting the importance of balancing rest and study. Improves online learning platforms by recommending optimal study times based on sleep cycles. Supports school administrators in considering later school start times to enhance student performance. Helps in early detection of sleep disorders (e.g., insomnia, sleep apnea) that may hinder academic success. Encourages development of mobile apps that track and optimize sleep for better study habits. Provides evidence for policy changes on reducing excessive homework loads to allow healthier sleep patterns. Contributes to neuroscience research exploring the link between memory consolidation and sleep.

Conclusion

The study clearly shows that sleep has a strong effect on how well students perform in their academics. Students who sleep for more hours on average are able to score higher marks.



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The positive correlation correlation ($r \approx 0.954$) proves that there is a strong link between sleep and academic performance, and the regression equation $\hat{Y} = 27.667 + 5.3331X$ shows that every extra hour of sleep can improve marks by about five points. This means that proper sleep is not just a health factor, but also an important part of improving academic success.

From this result, it is recommended that students should follow a proper sleep routine to keep their minds fresh and active. Going to bed and waking up at the same time everyday helps the body stay in balance and makes it easier to focus in class. Students should also practice good sleep habits, such as keeping the bedroom calm and free from disturbances.

Using phones, laptops, or TVs before bed should be reduced because the light from screens can disturb sleep. Regular physical activity during the day also helps in getting sound sleep at night and keeps the body healthy. Schools and colleges can also guide students who face sleep difficulties by giving them advice and support so that they can avoid tiredness and poor concentration. In the long run, when students learn to value rest along with study, they can perform better and also stay healthier.

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Full Length Article

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Optimization of Inventory Model Using Hexagonal Fuzzy Number

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Abstract

In this paper total inventory cost was minimized under Hexagonal fuzzy numbers. The parameters such as carrying cost and ordering cost were given in Hexagonal Fuzzy Numbers. The fuzzy numbers are defuzzified into crisp number by applying Magnitude ranking technique and Pascal's ranking technique. Numerical example were given to illustrate the comparison of total inventory cost obtained using fuzzy environment and classical inventory model under different defuzzification techniques. Sensitivity analysis for various demands were also discussed for various defuzzification techniques.

Keywords: Fuzzy Inventory Models, Hexagonal fuzzy numbers, Magnitude Ranking Technique, Pascal's ranking technique

Introduction

Operations Research is an important tool for the decision maker to create an alternative and to analyze an alternative in a effective way. Operations research methods are very often used in management science, economic, mathematics, industrial engineering and statistics. The main objective of operations research deals to get the best course of action of a decision-making problem under certain constraints. Inventory models are the mathematical framework which is used to control and manage the inventory to overcome the shortages. The primary goal of the inventory problem is to determine the optimum order quantity with the specified ordering cost, holding cost etc.



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Zadeh [9] introduced the idea of fuzzy set theory to manage many decision making problems and plays a vital role to overcome vagueness .In many decision making analysis fuzzy sets helps to yield the better results. Here fuzzy numbers determine the closest approach to the traditional inventory models. R.M.Rajalakshmi and Michael Rosario[6] studied the fuzzy inventory model with allowable shortages using different fuzzy numbers. S. Hemalatha and K.

Annadurai [4] determined the optimum inventory value using pentagonal fuzzy numbers. Many researches[2,3,6,7,8] had spread their ideas in optimising the inventory cost.

Here the fuzzy inventory model with ordering cost and holding cost were being considered in Hexagonal fuzzy number which are further defuzzified into crisp value by using

Magnitude and Pascal's ranking technique .The results obtained were compared with traditional inventory model and further with the other ranking techniques ,it was observed that the result yield by using Magnitude ranking method yield better results. Further sensitivity analysis for various demands were also done.

Fuzzy number

Let $\tilde{A}$ be a fuzzy set defined on R the set of real numbers is a Fuzzy number if

$\mu_{\tilde{A}}(x): R \rightarrow [0,1]$ is called the membership function if it satisfies the following characteristics.

(i) $\tilde{A}$ is normal. It means there exists an $x \in R$ such that $\mu_{\tilde{A}}(x) = 1$ (ii) $\tilde{A}$ is convex. It means for every $x_1, x_2 \in R$

$\mu_{\tilde{A}}(px_1 + (1 - p)x_2) \geq \min\{\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)\}$ where $p \in \{0,1\}$ (iii) $\mu_{\tilde{A}}(x)$ is an upper semi - continuous membership function.

Fuzzy set

Let X be a universal set. A Fuzzy Set $\tilde{A}$ is defined by a membership function $\mu_{\tilde{A}}(x): X \rightarrow [0,1]$ where $\mu_{\tilde{A}}$ is the degree of membership of $x \in X$ in the set $\tilde{A}$ and is denoted by

$\tilde{A} = \{(x, \mu_{\tilde{A}}(x)); x \in X\}$ Hexagonal fuzzy number:

A fuzzy number H HFN = $(a_1, a_2, a_3, a_4, a_5, a_6)$ is a hexagonal fuzzy number and its membership function is given by.



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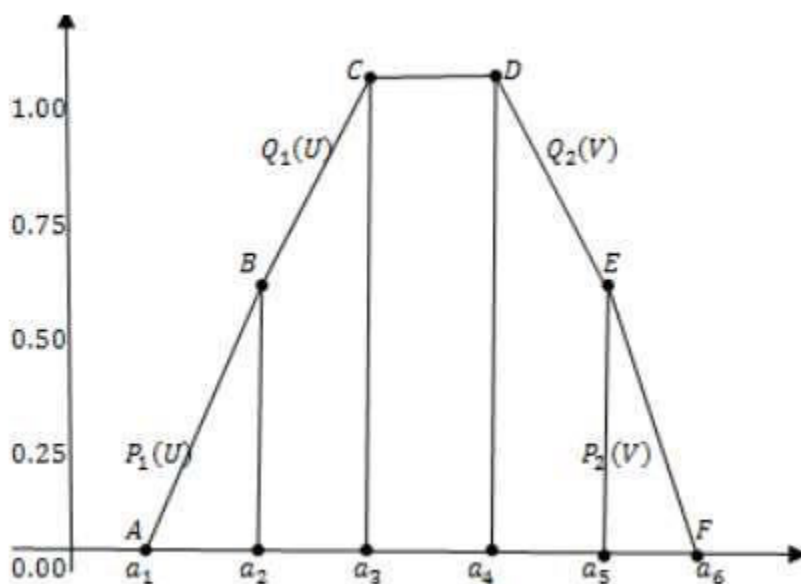
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$$\mu_{\tilde{H}}^{HFN}(x) = \begin{cases} 0 & \text{for } x < a_1 \\ \frac{1}{2} \left(\frac{x-a_1}{a_2-a_1} \right) & \text{for } a_1 \leq x \leq a_2 \\ \frac{1}{2} + \frac{1}{2} \left(\frac{x-a_2}{a_3-a_2} \right) & \text{for } a_2 \leq x \leq a_3 \\ 1 & \text{for } a_3 \leq x \leq a_4 \\ 1 - \frac{1}{2} \left(\frac{x-a_4}{a_5-a_4} \right) & \text{for } a_4 \leq x \leq a_5 \\ \frac{1}{2} \left(\frac{a_6-x}{a_6-a_5} \right) & \text{for } a_5 \leq x \leq a_6 \\ 0 & \text{for } x > a_6 \end{cases}$$

where $a_1, a_2, a_3, a_4, a_5, a_6$ are real numbers.





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Arithmetic operations of Hexagonal fuzzy number

Let $\tilde{P} = (p_1', p_2', p_3', p_4', p_5', p_6')$ and $\tilde{Q} = (q_1', q_2', q_3', q_4', q_5', q_6')$ be two hexagonal fuzzy numbers, then

Addition

$$\tilde{P} + \tilde{Q} = (p_1' + q_1', p_2' + q_2', p_3' + q_3', p_4' + q_4', p_5' + q_5', p_6' + q_6')$$

Subtraction

$$\tilde{P} - \tilde{Q} = (p_1' - q_1', p_2' - q_2', p_3' - q_3', p_4' - q_4', p_5' - q_5', p_6' - q_6')$$

Multiplication

$$\tilde{P}\tilde{Q} = (p_1' \times q_1', p_2' \times q_2', p_3' \times q_3', p_4' \times q_4', p_5' \times q_5', p_6' \times q_6')$$

Notations and Assumptions

Here the proposed model is executed under the following notations

TC : Total Inventory Cost

H : Holding cost per unit time

Q : Optimum Order Quantity per cycle

K : Ordering cost per unit time

D : Demand rate

T : Total length of the plan

Q*:Fuzzy Optimum Order Quantity

$\tilde{H}$: Fuzzy Holding cost per unit time

$\tilde{K}$: Fuzzy Ordering cost per unit time

FTC : Fuzzy Total Inventory Cost Assumptions: o Demand rate is constant o Ordering cost, Holding cost, are being taken as hexagonal fuzzy numbers. o Shortage cost is not allowed o Time plan is constant

Proposed Inventory Model

Assuming the following cost:

KD



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$$\text{Holding Cost} = \frac{Q}{2}$$

$$\text{Ordering Cost} = \frac{HQ}{2}$$

$$\text{Total Inventory Cost : } TC = \frac{KD}{Q} + \frac{HQ}{2} \dots\dots\dots(1)$$

$$\text{In order to find the total cost equate } \frac{\partial TC}{\partial Q} = 0 \text{ and } \frac{\partial^2 TC}{\partial Q} > 0$$

$$\frac{\partial TC}{\partial Q} = -\frac{KD}{Q^2} + \frac{H}{2}$$

$$-\frac{KD}{Q^2} + \frac{H}{2} = 0$$

$$\text{Getting the value of } Q = \sqrt{\frac{2DK}{H}} \dots\dots\dots(2)$$

Ranking Methods :

$$\text{Magnitude Ranking Technique : } R(HFN) = \frac{a_1+2a_2+2a_3+2a_4+2a_5+a_6}{10}$$

$$\text{Pascal's Ranking Technique : } R(HFN) = \frac{a_1+5a_2+10a_3+10a_4+5a_5+a_6}{32}$$

Proposed Fuzzy Inventory Model

In this model holding cost and ordering cost are taken as Hexagonal fuzzy numbers.

$\tilde{K} = (K_1, K_2, K_3, K_4, K_5, K_6)$, $\tilde{H} = (H_1, H_2, H_3, H_4, H_5, H_6)$, The fuzzy inventory model are given as

$$TC = \left\{ \left(\frac{K_1 D}{Q} + \frac{H_1 Q}{2} \right), \left(\frac{K_2 D}{Q} + \frac{H_2 Q}{2} \right), \left(\frac{K_3 D}{Q} + \frac{H_3 Q}{2} \right), \left(\frac{K_4 D}{Q} + \frac{H_4 Q}{2} \right), \left(\frac{K_5 D}{Q} + \frac{H_5 Q}{2} \right), \left(\frac{K_6 D}{Q} + \frac{H_6 Q}{2} \right) \right\}$$

$$FTC = \frac{1}{10} \left\{ \left(\frac{K_1 D}{Q} + \frac{H_1 Q}{2} \right) + 2 \left(\frac{K_2 D}{Q} + \frac{H_2 Q}{2} \right) + 2 \left(\frac{K_3 D}{Q} + \frac{H_3 Q}{2} \right) + 2 \left(\frac{K_4 D}{Q} + \frac{H_4 Q}{2} \right) + 2 \left(\frac{K_5 D}{Q} + \frac{H_5 Q}{2} \right) + \left(\frac{K_6 D}{Q} + \frac{H_6 Q}{2} \right) \right\}$$



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$$FTC = \frac{(K_1 + 2K_2 + 2K_3 + 2K_4 + 2K_5 + K_6)D}{10Q} + \frac{(H_1 + 2H_2 + 2H_3 + 2H_4 + 2H_5 + H_6)Q}{20} \dots (3)$$

By equating $\frac{\partial(FTC)}{\partial Q} = 0$ the fuzzy optimum cost were obtained

$$\frac{1}{10} \left\{ -\frac{D}{Q^2} (K_1 + 2K_2 + 2K_3 + 2K_4 + 2K_5 + K_6) + \frac{1}{2} (H_1 + 2H_2 + 2H_3 + 2H_4 + 2H_5 + H_6) \right\} = 0$$

$$(i.e) Q^* = \sqrt{\frac{2D(K_1+2K_2+2K_3+2K_4+2K_5+K_6)}{(H_1+2H_2+2H_3+2H_4+2H_5+H_6)}} \dots\dots\dots(4)$$

Algorithm:

Step 1: Calculate optimum inventory model using traditional inventory method. Step 2: Defuzzify the parameters given in Hexagonal fuzzy numbers using Magnitude

Ranking technique,

Step 3: Determine fuzzy total cost (FTC) using fuzzy arithmetic operations on fuzzy carrying and holding cost which is taken as heptagonal fuzzy numbers. Obtain the value of fuzzy optimum quantity by finding the first derivatives of FTC and equating to zero, where the second derivatives of FTC is positive.

Step 4: Compare the optimum value with fuzzy model and traditional inventory model.

Step 5: Sensitivity analysis for various demand rate were calculated.

Numerical Example

(i) Under Magnitude Method

Let us assume the data with $D = 700$, $K = 9$, $= 0.7$ find the optimum order quantity and total cost using inventory model. Here K , H are considered as hexagonal fuzzy numbers. $\tilde{K} =$

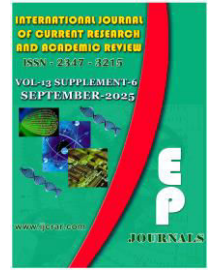


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(3,7,8,10,12,13), $\tilde{H} = (0.2, 0.4, 0.6, 0.8, 1, 1.2)$ then find the optimal order quantity and total cost under fuzzy environment.

Solution :

Step 1: Given with $D = 700$, $K = 9$, $H = 0.7$

$$Q = \sqrt{\frac{2DK}{H}} = 134.16$$

$$TC = \frac{KD}{Q} + \frac{HQ}{2} = 93.91$$

Step 2: Fuzzy Optimum Order Quantity

$$\tilde{Q}^* = \sqrt{\frac{2D(K_1 + 2K_2 + 2K_3 + 2K_4 + 2K_5 + K_6)}{(H_1 + 2H_2 + 2H_3 + 2H_4 + 2H_5 + H_6)}} = 134.16$$

Step 3 : Fuzzy Model

$$FTC = \frac{1}{10} \left\{ \left(\frac{K_1 D}{Q} + \frac{H_1 Q}{2} \right) + 2 \left(\frac{K_2 D}{Q} + \frac{H_2 Q}{2} \right) + 2 \left(\frac{K_3 D}{Q} + \frac{H_3 Q}{2} \right) + 2 \left(\frac{K_4 D}{Q} + \frac{H_4 Q}{2} \right) + 2 \left(\frac{K_5 D}{Q} + \frac{H_5 Q}{2} \right) + \left(\frac{K_6 D}{Q} + \frac{H_6 Q}{2} \right) \right\}$$

$$FTC = \frac{(K_1 + 2K_2 + 2K_3 + 2K_4 + 2K_5 + K_6)D}{10Q} + \frac{(H_1 + 2H_2 + 2H_3 + 2H_4 + 2H_5 + H_6)Q}{20}$$

$$FTC = 93.90$$

Step 4: Comparative analysis

Traditional Method: $Q = 134.16$, $TC = 93.91$

Fuzzy Method : $Q^* = 134.16$, $FTC = 93.90$



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Sensitivity Analysis for Demand

S.No	D	Q	TC	Q*	FTC
1	800	143.42	100.39	143.42	100.32
2	900	152.12	106.48	152.12	106.48
3	1000	160.35	112.24	160.35	112.21
4	1100	168.18	117.72	168.18	117.72
5	1200	175.66	122.96	175.66	122.96

The sensitivity analysis reveals that when the demand rate increases, both the economic lot size and inventory cost increases. But remains same for both the classical method and fuzzy environment.

(ii) Under Pascal's Ranking Method

Let $\tilde{K} = (K_1, K_2, K_3, K_4, K_5, K_6)$, $\tilde{H} = (H_1, H_2, H_3, H_4, H_5, H_6)$, The fuzzy inventory model are given as

$$\begin{aligned}
 TC &= \left\{ \left(\frac{K_1 D}{Q} + \frac{H_1 Q}{2} \right), \left(\frac{K_2 D}{Q} + \frac{H_2 Q}{2} \right), \left(\frac{K_3 D}{Q} + \frac{H_3 Q}{2} \right), \left(\frac{K_4 D}{Q} + \frac{H_4 Q}{2} \right), \left(\frac{K_5 D}{Q} + \frac{H_5 Q}{2} \right), \left(\frac{K_6 D}{Q} + \frac{H_6 Q}{2} \right) \right\} \\
 FTC &= \frac{1}{32} \left\{ \left(\frac{K_1 D}{Q} + \frac{H_1 Q}{2} \right) + 5 \left(\frac{K_2 D}{Q} + \frac{H_2 Q}{2} \right) + 10 \left(\frac{K_3 D}{Q} + \frac{H_3 Q}{2} \right) + 10 \left(\frac{K_4 D}{Q} + \frac{H_4 Q}{2} \right) + 5 \left(\frac{K_5 D}{Q} + \frac{H_5 Q}{2} \right) + \left(\frac{K_6 D}{Q} + \frac{H_6 Q}{2} \right) \right\} \\
 FTC &= \frac{(K_1 + 5K_2 + 10K_3 + 10K_4 + 5K_5 + K_6)D}{32Q} + \frac{(H_1 + 5H_2 + 10H_3 + 10H_4 + 5H_5 + H_6)Q}{64} \dots\dots\dots(5)
 \end{aligned}$$

By equating $\frac{\partial(FTC)}{\partial Q} = 0$ the fuzzy optimum cost were obtained



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$$\frac{1}{32} \left\{ -\frac{D}{Q^2} (K_1 + 5K_2 + 10K_3 + 10K_4 + 5K_5 + K_6) + \frac{1}{2} (H_1 + 5H_2 + 10H_3 + 10H_4 + 5H_5 + H_6) \right\} = 0$$

$$(i.e) Q^* = \sqrt{\frac{2D(K_1 + 5K_2 + 10K_3 + 10K_4 + 5K_5 + K_6)}{(H_1 + 5H_2 + 10H_3 + 10H_4 + 5H_5 + H_6)}} \dots \dots \dots (6)$$

The same algorithm will be followed for the Pascal's ranking technique. In the above numerical example step 1 gives the same results.

Step 2: Fuzzy Optimum Order Quantity

$$\tilde{Q}^* = \sqrt{\frac{2D(K_1 + 5K_2 + 10K_3 + 10K_4 + 5K_5 + K_6)}{(H_1 + 5H_2 + 10H_3 + 10H_4 + 5H_5 + H_6)}} = 134.16$$

Step 3 : Fuzzy Model

$$FTC = \frac{1}{32} \left\{ \left(\frac{K_1 D}{Q} + \frac{H_1 Q}{2} \right) + 5 \left(\frac{K_2 D}{Q} + \frac{H_2 Q}{2} \right) + 10 \left(\frac{K_3 D}{Q} + \frac{H_3 Q}{2} \right) + 10 \left(\frac{K_4 D}{Q} + \frac{H_4 Q}{2} \right) + 5 \left(\frac{K_5 D}{Q} + \frac{H_5 Q}{2} \right) + \left(\frac{K_6 D}{Q} + \frac{H_6 Q}{2} \right) \right\}$$

$$FTC = \frac{(K_1 + 5K_2 + 10K_3 + 10K_4 + 5K_5 + K_6)D}{32Q} + \frac{(H_1 + 5H_2 + 10H_3 + 10H_4 + 5H_5 + H_6)Q}{64}$$

$$FTC = 94.40$$

Step 4: Comparative analysis

Traditional Method: $Q = 134.16$, $TC = 93.91$

Fuzzy Method : $Q^* = 134.16$, $FTC = 94.40$



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Sensitivity Analysis for Demand

S.No	D	Q	TC	Q*	FTC
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3	1000	160.35	112.24	161.18	112.81
4	1100	168.13	117.72	169.05	118.33
5	1200	175.66	122.96	176.57	123.59

The sensitivity analysis reveals that when the demand rate increases, both the economic lot size and inventory cost increases. But there is variations in the fuzzy environment.

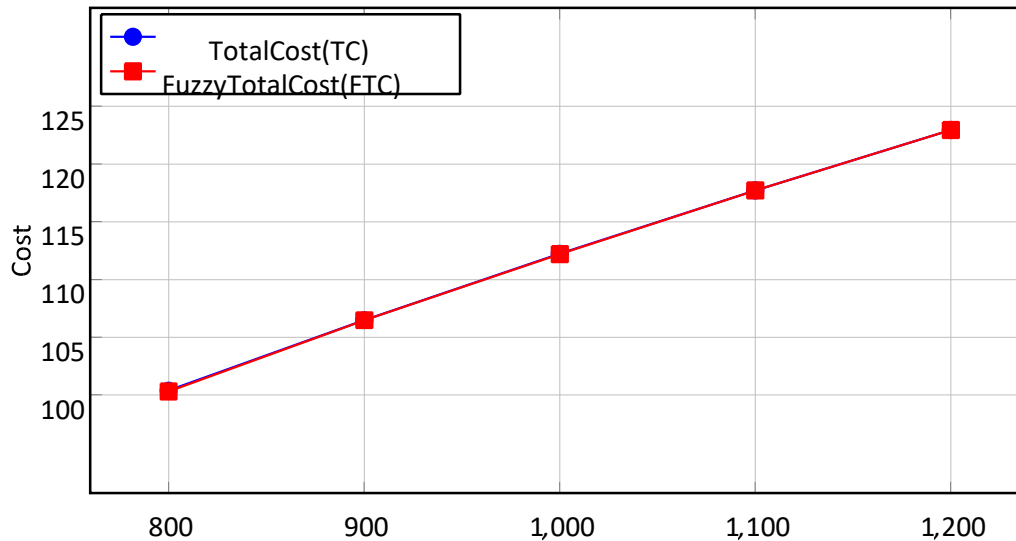


Figure 1: Graphical Representation for sensitivity analysis for demand under Magnitude ranking technique.



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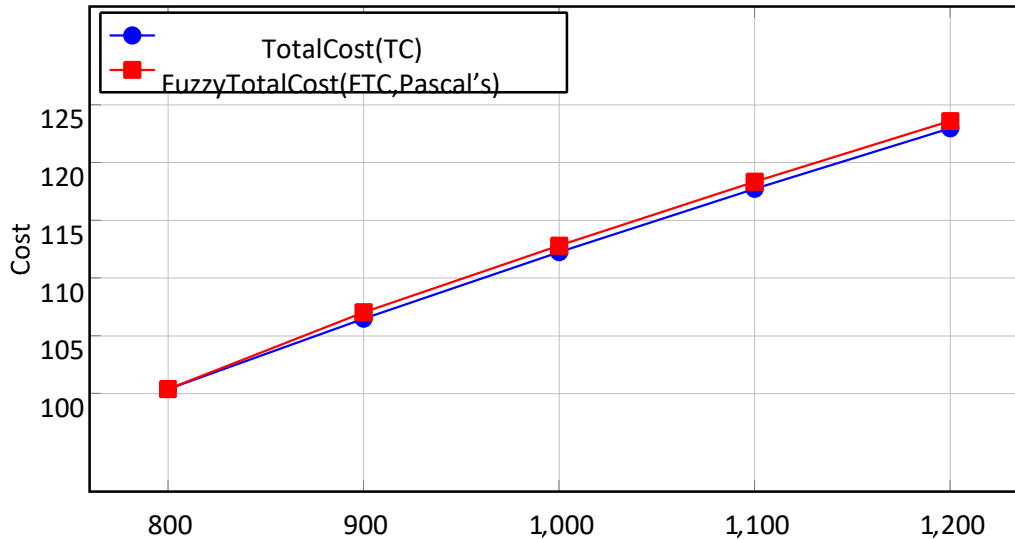


Figure 2: Graphical Representation for sensitivity analysis for demand under Pascal's ranking technique

Conclusion

Here the total inventory cost was minimized under Hexagonal fuzzy numbers under various defuzzification techniques. Comparison were done in conventional method and fuzzy environment the results depict that the fuzzy environment under magnitude method yields better results when compared with the Pascal's ranking technique.

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Full Length Article

IJCRAR/FL/74

Shortest Path Algorithms in Graph Theory

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Abstract

Graph theory provides a powerful framework for solving problems in computer science, mathematics, and real-world systems. One of the fundamental problems in graph theory is the shortest path problem, which seeks the minimum distance between two vertices in a weighted graph. In this paper, we study and compare two important algorithms for solving the shortest path problem: Dijkstra's Algorithm and Bellman-Ford Algorithm. A worked example is presented to illustrate the step-by-step process of both methods. The results show that while Dijkstra's Algorithm is efficient for graphs with non-negative weights, the Bellman-Ford Algorithm can also handle negative weights, though at a higher computational cost. Applications in navigation, computer networks, and operations research highlight the practical importance of these algorithms.

Keywords: Graph Theory, Shortest Path Problem, Dijkstra's Algorithm, Bellman-Ford Algorithm, Weighted Graphs, Applications

Introduction

Graph theory is an important branch of mathematics that studies the relationships between objects through vertices and edges. It provides the foundation for solving many problems in computer science, operations research, and network analysis. One of the most widely studied problems in graph theory is the shortest path problem, which aims to determine the path of minimum length or cost between two vertices in a graph. Shortest path problems arise in many real-life situations such as finding the quickest route in transportation systems, designing efficient computer networks, and pathfinding in artificial intelligence and games. To solve this problem, various algorithms have been developed, each with different advantages and limitations. In this paper, we focus on two well-known algorithms:



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Dijkstra's Algorithm and Bellman-Ford Algorithm. Dijkstra's Algorithm is efficient for graphs with non-negative edge weights, while Bellman-Ford is more versatile, as it can handle negative edge weights at the cost of higher time complexity. A worked example is presented to compare the two methods and to highlight their practical use in real-world applications.

Basics of Graph Theory

A graph is a mathematical structure that represents a set of objects and the relationships between them. The objects are called vertices (or nodes), and the connections between them are called edges. A graph is usually denoted as $G=(V, E)$, where V is the set of vertices and E is the set of edges. Graphs can be classified into different types[5]:

1. Directed Graph (Digraph): An edge has a direction, representing one-way connections.
2. Undirected Graph: An edge represents a two-way connection between vertices.
3. Weighted Graph: Each edge is assigned a numerical value (weight or cost), often representing distance, time, or cost.
4. Unweighted Graph: All edges are considered to have equal weight.

In the context of the shortest path problem, weighted graphs are most relevant, since the objective is to find the path between two vertices with the smallest total weight. For example, in a road network, vertices represent cities and edge weights represent distances between them.

Shortest Path Problem:

The shortest path problem is one of the most fundamental and widely studied problems in graph theory. It can be formally defined as follows: given a weighted graph $G=(V, E)$, and two vertices s (source) and t (destination), the objective is to find a path from s to t such that the sum of the edge weights along the path is minimized.

There are several variations of the shortest path problem:

1. Single-source shortest path: Find the shortest paths from a given source vertex to all other vertices in the graph.
2. Single-destination shortest path: Find the shortest paths from all vertices in the graph to a single destination vertex.
3. All-pairs shortest path: Find the shortest paths between every pair of vertices in the graph.



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The problem is important because it appears in many real-world applications such as GPS navigation, airline scheduling, internet routing, and supply chain optimization. Different algorithms have been designed to solve the shortest path problem efficiently. Among them, Dijkstra's Algorithm and Bellman-Ford Algorithm are two of the most commonly used approaches, each with its own strengths and limitations.

Dijkstra's Algorithm

Dijkstra's Algorithm, proposed by Edsger W. Dijkstra in 1956[2], is one of the most widely used methods for solving the shortest path problem in graphs with non-negative edge weights. It works by repeatedly selecting the vertex with the minimum distance value and updating the distances to its neighboring vertices until the shortest path is found.

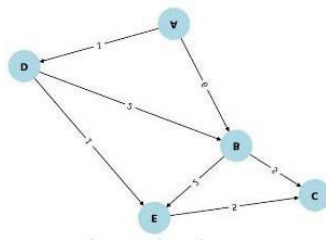
Steps of Dijkstra's Algorithm:

Assign to every vertex a tentative distance: 0 for the source vertex and ∞ (infinity) for all others.

1. Mark all vertices as unvisited. Set the source as the current vertex.
2. For the current vertex, check all its neighbors. If a shorter path to a neighbor is found, update its distance.
3. After checking all neighbors, mark the current vertex as visited. A visited vertex will not be checked again.
4. Select the unvisited vertex with the smallest tentative distance and set it as the new current vertex.
5. Repeat steps 3-5 until all vertices are visited or the destination is reached.

Worked Example

Consider a graph with vertices A, B, C, D, E and the following weighted edges:





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We want to find the shortest path from A to C. Step Step 1: Initialization

- Distance(A) = 0
- Distance(B, C, D, E) = ∞

Step 2: Start at A

- Neighbors: B = 6, D = 1
- Update Distance(B)=6, Distance(D)=1

Step 3: Choose smallest (D=1)

- D $\rightarrow$ B = 1+2=3 $\rightarrow$ update Distance(B)=3 (better than 6)
- D $\rightarrow$ E = 1+1=2 $\rightarrow$ update Distance(E)=2

Step 4: Choose smallest (E=2)

- E $\rightarrow$ C = 2+5=7 $\rightarrow$ update Distance(C)=7

Step 5: Choose smallest (B=3)

- B $\rightarrow$ C = 3+5=8 $\rightarrow$ no update (C already 7)
- B $\rightarrow$ E = 3+2=5 $\rightarrow$ no update (E already 2)

Step 6: Choose smallest (C=7)

Shortest Path from A $\rightarrow$ C = 7 Path:

A $\rightarrow$ D $\rightarrow$ E $\rightarrow$ C

Bellman-Ford Algorithm

The Bellman-Ford Algorithm, developed by Richard Bellman and Lester Ford[3][4], is another important method for solving the shortest path problem. Unlike Dijkstra's Algorithm, Bellman-Ford can handle graphs that contain negative edge weights, as long as there are no negative weight cycles. It works by repeatedly relaxing all edges of the graph, gradually reducing the estimated shortest path distances.

Steps of Bellman-Ford Algorithm:

1. Assign to every vertex a tentative distance: 0 for the source vertex and ∞ (infinity) for all others.

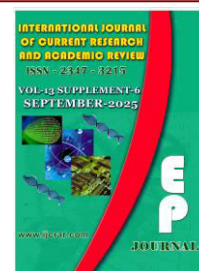


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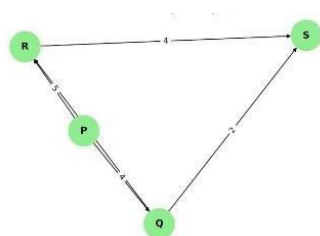
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2. For iterations (where is the number of vertices):
 - Go through every edge .
 - If $\text{Distance}(u) + \text{weight}(u, v) < \text{Distance}(v)$, then update $\text{Distance}(v)$.
3. After iterations, all shortest paths will be found.
4. Perform one more iteration over all edges to check for negative weight cycles. If a shorter path is still found, the graph contains a negative cycle.

Worked example

Vertices: P, Q, R, S



Initialization:

- $\text{Distance}(P) = 0$
- $\text{Distance}(Q, R, S) = \infty$

Iteration 1:

- $P \rightarrow Q = 4 \rightarrow \text{Distance}(Q)=4$
- $P \rightarrow R = 5 \rightarrow \text{Distance}(R)=5$
- $Q \rightarrow R = 4 + (-3) = 1 \rightarrow \text{update } \text{Distance}(R)=1$
- $Q \rightarrow S = 4 + 2 = 6 \rightarrow \text{Distance}(S)=6$
- $R \rightarrow S = 1 + 4 = 5 \rightarrow \text{update } \text{Distance}(S)=5$

Shortest Path $P \rightarrow S = 5$

Path: $P \rightarrow Q \rightarrow R \rightarrow S$

Comparison of Dijkstra and Bellman-Ford Algorithm:

Both Dijkstra's Algorithm and Bellman-Ford Algorithm are widely used to solve the shortest path problem, but they differ in efficiency and applicability.

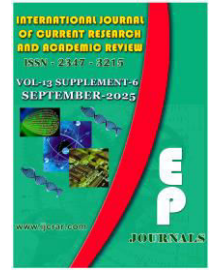


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- Dijkstra's Algorithm is faster and efficient for graphs with non-negative weights, making it suitable for large-scale applications like GPS navigation and network routing.
- Bellman-Ford Algorithm, though slower, is more versatile since it can handle negative edge weights and can also detect negative weight cycles.

Comparison Table

Edge Weights	Works only with non-negative edges	Works with negative edges (no cycles)
Time Complexity	$O(V^2)$ or $O(E + V \log V)$	$O(VE)$
Speed	Faster	Slower
Negative Cycle Detection	Cannot detect	Can detect
Applications	GPS, computer networks, AI pathfinding	Financial modeling, graphs with negative costs

Application of Shortest Path Algorithms

The shortest path problem is not only a theoretical concept in mathematics but also has wide applications in the real world. Some important applications include:

1. Navigation and GPS Systems

- Applications such as Google Maps and GPS devices use shortest path algorithms to compute the fastest or most efficient route between two locations.
- Dijkstra's Algorithm is commonly used in this context due to its efficiency.

2. Computer Networks

- In data communication, shortest path algorithms help in finding the most efficient path for transferring data packets between nodes in a network.



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- Protocols such as RIP (Routing Information Protocol) and OSPF (Open Shortest Path First) are based on these concepts[6].

3. Transportation and Logistics

- Airlines, railways, and supply chains use shortest path algorithms to minimize travel distance, cost, or time.
- Bellman-Ford is often useful when dealing with graphs that include varying costs or possible negative values (such as profit/loss calculations).

4. Artificial Intelligence and Games

- Pathfinding in AI (e.g., characters moving in a game environment) often requires computing shortest paths.
- Algorithms like Dijkstra's form the basis for more advanced AI pathfinding algorithms such as A*.

5. Operations Research

- Shortest path techniques are applied to solve optimization problems in project planning, scheduling, and resource allocation.

Conclusion

The shortest path problem is one of the most fundamental and widely studied topics in graph theory, with significant applications in mathematics, computer science, and real-life systems. In this paper, we studied two classical algorithms for solving the problem: Dijkstra's Algorithm and Bellman-Ford Algorithm. Through worked examples, it was shown that Dijkstra's Algorithm is highly efficient for graphs with non-negative weights, while Bellman-Ford is more versatile as it can handle negative weights and detect negative cycles, though at the cost of higher time complexity. Both algorithms remain essential tools for solving optimization problems, and their applications can be seen in navigation, network routing, artificial intelligence, and operations research. Future work in this area focuses on developing faster algorithms that can handle very large graphs, dynamic updates, and real-time data efficiently.



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Full Length Article

IJCRAR/FL/75

Exploring the Importance of Mathematics in Everyday Life Activities

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Abstract

Mathematics is frequently perceived as an abstract concept apprehended in the classroom or in algebraic thought processes. However, in reality, it constitutes a key approach for a natural human thought process, essential for analyzing everyday, scientific, and technological human activities. Despite the belief that traditional "soft" sciences can forgo a mathematical analysis, math is presently the only way of establishing a scientific thought process. Here in this work, the application of mathematics in various everyday activities is discussed. What are its roles and functions? How do we employ it? These inquiries are answered based on widely accessible knowledge, yet rarely considered agricultural, industrial, or commercial applications. Nevertheless, the hidden compelling simplicity, elegance, and beauty are also elaborated on here, to the extent human perception allows. Mathematics inherently belongs to science and technology, akin to a bird's winged structure. Therefore, it is distortive to fit a part of it into another, be it providing a definition of math separately from science, how to use it separately from giving examples of scientific methods in math, etc. Such "separations" are impossible. That would precisely be analogous to the definition of a bird as a winged and feathered animal separate from its characteristics or examples of its species. However, it would be truly ridiculous to suppose that anyone imagines what a bird is after such an explanation. There is a simple analogy: mathematics is to science as a bird is to a winged animal. However, there is a key difference: there are also elements, such as monkeys, that represent both. In a similar way, there is a group of sciences such as logic, linguistics, and psychology that belong to neither visible class, with fuzzy incoherence of definitions and understanding. Effectively, presently still highly debated issues such as those of innateness of mathematics understanding are impossible to understand without adequate definitions. Nonetheless, there are aspects established in human experience on how to build a scientific thought process. They are elucidated here in the simplest way, with widely accessible examples. It is attempted to structure the known knowledge regarding this issue in accordance with the particularly structured mathematical treatment, in this way building a first approximation roadmap easy to be expanded on.

Keywords: Mathematics In Everyday Life, Applications Of Mathematics, Finance And Budgeting

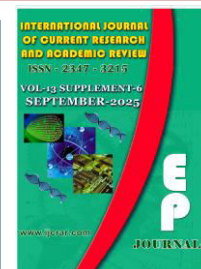


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Theoretical Framework

The aim of performing this activity is to explore the daily life applications of mathematics. Observation is the method used for data collection. The researcher has carried out the activity of daily life mathematics. Mathematics is often perceived as a difficult subject utilized solely for calculations. However, in reality, mathematics is utilized incessantly in every simple aspect of life. It is the only subject that is applicable in both scholarly and personal realms. Mentioning specific numerical examples, mathematics is applied while shopping for vegetable quantities, cake grams, and more. Other manipulations of calculation include calculating monthly salaries, splitting bills for transports, and distributing share and profit amounts among 3-4 members. This investigation focuses on the aspects of life where mathematics is utilized. Symbolical examples related to addressing bill amounts in shopping are included within this activity.

This research is expected to be informative for several individuals as mathematics interfacing is common among people. As science is releasable in different mathematics usages, mathematics research will be useful for the science domain. After conducting this activity, all the different aspects of daily life where mathematics is used have been noted. Various persons including home-makers and literate workers exhibit differences in threshold daily life mathematics quantities. While the analyzing results section includes a brief introduction in reflecting activities, the points of highlight significance should be readable by anyone. These points can also be a basis for further research about science interfacing with day-to-day mathematics aspects. On exploring the impact of mathematics in everyday life activities, it is noted that art as a domain receives the least scientific interfacing. Other interfacing can be classified in different standards irrespective of the number of aspects. As science methodology is applied in analyzing aspects, mathematic domain interfacing is the only simple analysis. Mathematics must be a compulsory item for every domain to conduct commencing with schooling to higher studies.

Mathematics In Everyday Life

Mathematics is often viewed as an abstract and theoretical subject. However, it is a discipline that is utilized in various applications in everyday life. Mathematics enables people to



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analyze, organize, and observe the different activities that are encountered daily. It is considered as a human creation and provides conceptual tools needed to model, investigate, and understand both the natural and constructed worlds. A mathematical context refers to the familiar situation in which certain mathematical procedures are applicable, and mathematical literacy is citizens' ability to understand and deal with the role that mathematics plays in the world. Mathematics is deeply involved in people's daily activities. It is necessary for life. It exists and is applied everywhere by people in every modern society. The day-to-day tasks of people in their personal lives and in their work environment cannot be accomplished without using mathematics. Thus, it appreciates the fact that mathematics is there in everyday life.

The notion that mathematics is found in daily life is important because when one states that mathematics is in daily life, it emphasizes that the mathematics discussed is not just confined to the classroom or school mathematics. Math is utilized as a way of thinking critically or problem-solving in analyzing situations. It controls life and is either used or manipulated. Certain guidelines and remarks are part of the understanding of everyday life mathematics. Everyday life mathematics entails official mathematics in terms of institutionalized mathematics, all formal mathematics, semi-formal mathematics that is taught in schools, and informal mathematics that emerges in home, community, and occupational settings. Learning mathematics is a lifelong process and employs a new beginning at any moment of life. It is necessary for survival and makes a person astute, sharp, informative, smart, and cunning. Mathematics is for human beings and human beings have always known how to use it in their affairs. Aborigines or primitive societies have their own mathematics that suffices for meeting their needs. Mathematics is a universal faculty, a fundamental cognitive capacity to see patterns or relationships in experience. Likewise, numbers are a universal faculty and language common to all cultures.

Methodology

The study of the importance of mathematics in everyday life activities has been approached through the theoretical framework of science, with a focus on the scientific methodology. This science-oriented methodology integrates the concepts of mathematics, its evolutionary phases, time, space, theory, experiment, model, and paradigm in a holistic manner. To study the importance of mathematics in daily life activities in particular, and to study any



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scientific knowledge and its importance in general, the in-depth notions of the evolutionary phases of knowledge (Phase I, Phase II, and Phase III) and of the higher and lower dimensions of knowledge in harmony with time and space have been proposed, developed, and practiced.

The outcome of an exploratory study with this theoretical framework reveals that:

- 1) Mathematics gradually became evident as a full-fledged knowledge as it evolved through a series of gradually higher dimensional advances (Phase I: Lower Dimension Discovery and Theory-based Advancement; Phase II: Higher Dimension Paradigm-based Advancement) and then crystallized into a full-fledged knowledge in harmony with time and space
- 2) Universally best possible discovery or invention outcome of humans. The humanity or knowledge universe is considered as a huge dynamic cosmos where knowledge is imagined, invented, discovered, and developed as higher dimensional "strategies" in harmony for survival, sustenance, and advancement on lower dimensional earth or solar system. Mathematics, in particular, and any scientific knowledge in general, is higher dimensional knowledge or theory or paradigm-based approach, practice, and discovery.
- 3) "Importance" is a higher dimensional concept. For example, it is "very important" for temporally illiterate developing countries, "also important" to literate countries, and "insignificantly important" for knowledge/time higher dimensional countries.
- 4) The translation of mathematics in everyday life activities (ELAs) brings this dimension of importance in practical perspectives.
- 5) The past complement-false dimension gap and harmony with time and space concordance bring a transformation on earth dimension, knowledge experimental data-mathematics paradigm, and linguistic daily life activity practical basis.

Scientific Approach To Studying Mathematics In Everyday Life

Mathematics involves abstract concepts such as quantity, structure, space, equations, and changes, which can be represented through numbers, symbols, vectors, diagrams, and equations. Everyday life is defined as the typical activities of persons in personal, educational, or social contexts, including anything that occurs in routine life or standard situations. The research objective focuses on identifying mathematical activities in daily life, particularly relating to planned and executed local activities. A geographical perspective emphasizes the significance of



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place and space. Hence, the intent is to discover the quantity of mathematics embedded in daily activities and the perception of importance and difficulty in the local treatment of it. The concerned population comprises students of Classes IV and V of SDN Sipak, Citeureup, Bogor, West Java. The method utilizes the scientific approach comprising systematic steps: Observations, Questions, Exploration, Association/Reasons, Conclusion, and Re-Observation. The research is fieldwork-based or fieldwork as a research basis, depicting the setting, interactions, and problems in natural patterns as they occur in daily life. The local theme ensures closeness and relevance and facilitates understanding by focusing on the local and common so that they are more familiar.

Observations are initial activities to collect information on mathematical activities regarding the selection of plants, fruits, and flowers to be planted and maintained in the yard. The selection concerns the number/quantity of plants, flowers, and fruit trees based on the area/size of the land. This area is calculated in square meters using a calculation method and mathematical calculations. Simple calculations consist of gathering the available plants and comparing the number of plants observed. Questions arise from the observation process concerning mathematical aspects of everyday life activities. It focuses on planned and executed activities, indicating technology and mathematics components and involving mathematics in local activities. The mathematical design consists of exploring plant species options comprising fruits and flowers planted in the garden. Tracing local treatment mathematically allows for the local quantitative activity of distance, area, and capacity as part of room design, which can be a design theme of the learning process.

Applications of Mathematics in Various Everyday Life Activities

Mathematics is commonly regarded as a complex subject that revolves around numbers, formulas, graphs, and charts and entails the application of different operations and techniques. However, the significance of mathematics in daily life is usually unnoticed. The fact is that mathematics has immense relevance in real life, especially in shaping a person's lifestyle and molding their character. Mathematics plays a pivotal role in diverse facets of life such as banking, finance, shopping, cooking, travel, sports, education, measurements, time, clothes, business, health, and many more. The applications of mathematics in everyday life should not only be studied conventionally but should also be understood as it relentlessly functions and



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acts in various daily life activities. With the advancement of modern education, mathematics has now emerged as a significant subject and is a part of the essential educational curriculum in schools and colleges. Due to the growth of some professions like research, intelligence, finance, and equipment development, mathematics has attained prime significance in the field of education.

Finance and budgeting are two essential elements of life that require mathematics in daily activities. People usually live on a budget where they make a calculation on the cash in hand and the cash remaining after spending and depositing. The balance of this will reveal the budget of a person. Houses are bought with the help of loans, and the EMI is repaid monthly, depending on the tenure, rate of interest, and principal amount. A simple interest loan is the cheapest one, while compound interest is a more expensive loan on which high interest is paid off. In a similar vein, fixed deposit schemes are opted where every month a fixed amount is deposited to the bank, and at the span of a certain period, maturity is received back with interest. Therefore, finance and budgeting almost always require the calculations of simple interest, compound interest, percentage, division, addition, and so on.

Mathematics is also used in cooking and baking in daily life activities. Cooking often requires measuring the weight of the items or counting the number of ingredients, which are mathematical problems. Even the cooking times are based on mathematics and depend on the weight of the component, i.e. if further time is necessary for more weight, the time again needs to be calculated. In baking, the precise amount of flour, cake bread weight in grams, etc. is used based on pan size and ingredient density. Here weight and density play a vital role, which is again a mathematical concept. Apart from this, to bake a cake, the infra-red radiation of the oven here is placed in terms of Fahrenheit and time duration which needs to be explored. Therefore cooking and baking are also surrounded by mathematics problems.

Home DIY projects are another everyday activity that revolves around various types of mathematical concepts. Flat pack furniture is generally bought from IKEA, and the DIY projects often require simple steps where calculating the sizes, areas, and surface areas are to be discovered. Building a birdhouse from wood involves problems of calculating the area and cutting the right dimension. Similarly, growing plants on a vertical garden wall requires calculations on the height and width of the pot, number of plants per square meter, etc.



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Designing clothes, making photo frames or craft projects involve geometry or symmetry, so that the shapes look pleasing and nice. Painting whiteboard surfaces in rectangles or picking up area carpets always includes calculating the area of the surface to be covered. Therefore there are lots of day-to-day DIY home projects that come up with mathematical problems that require a systematic approach toward solving.

Finance and Budgeting

Many people believe that mathematics is no longer required after school. However, mathematics plays an important role in various everyday life activities that are taken for granted. Finance and budget is an area of everyday life that frequently uses mathematics without most individuals even realizing it. Whether it is about personal loan, transfer of funds, interest on fixed deposit, or tracking of the monthly expenditure, mathematics is intricately involved in such financial transactions. This article examines the use of mathematics in everyday life focusing on finance and budget.

Financial transactions involve digits from 0-9. Thus, every financial transaction is a numerical value in the number line. Based on place value system, mathematical operations such as addition, subtraction, multiplication, or division can be applied for any financial transaction. Number sense is an essential skill needed to comprehend and carry out calculations for such financial transactions. Generally, school-going children are expected to learn and develop number sense. To be proficient in number sense, learners should develop an understanding of numerical values and their relationships. For example, grasping the concept of tens and units in a number 81. Each digit in the number has a specific place value. In this case, 8 denotes 80 and 1 denotes 1. Understanding place value can help to do different computations in multiple ways such as expansion, rounding number, or performing operations on numbers.

Generally, a homemaker, retired person, or students who are not a professional accountant would deal with household budget and monetary transactions. In such instances, finance and budget is tracked using pencil and paper. Accounting is a systematic formal record-keeping process of financial transactions. Generally, large-scale companies maintain accounting journals, ledgers, and trial balance involving debit, credit, cash book, and bills. Although finance and budget computations involve basic operations, people still face difficulty in handling these

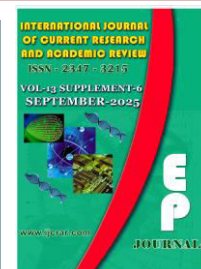


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computations. A simple computation such as $7.76/0.26$ can lead to massive errors in everyday life.

Finance and budget based on addition, subtraction, multiplication, or division is simple and straightforward. Still, it can lead to calculation errors affecting daily life. Errors in number-based computation frequently occur due to various reasons such as human error, transposition error, and outside disturbance. The perspective of understanding accidental errors in larger financial transactions can be a life learning lesson. It could lead to severe consequences such as imprisonment, being sent behind bars, or bankruptcy.

Cooking and Baking

Mathematics is essential in cooking and baking tasks. Whether for personal enjoyment or as a vocation in restaurants or bakeries, various measurements are required, from dry and wet ingredients to the amounts of flavoring and spices used. Many cooking measurements are based on American and British standards. Common measurements are on spoons and cups, with cup measurements considered large because they can measure liquid ingredients. Spoon measurements are small and precise. In cooking, several conversions are necessary for different recipes, especially where the conversions involve centimeters and inches for dry ingredients and milliliters, liters, and gallons for liquid measurements.

On the other hand, baking requires accurate measurements, so converting recipes is a little tedious, although it is essential to know. Many kitchen scales measure and convert weight measurements and different kinds of liquid measurements. Though considered a strong subject as part of the school curriculum, a little struggle in cooking and baking mathematics is not a shame. Consider knowing only the basics in cooking and baking measurements. Several common cooking and baking measurements.

Common Cooking Measurements

1 cup = 8 oz. $1/2$ cup = 4 oz. $1/3$ cup = $2\frac{3}{4}$ oz. $1/4$ cup = 2 oz. 1 tbsp. = 3 tsp. 1 tbsp. = 0.5 oz. 1 tsp. = $1/2$ tbsp

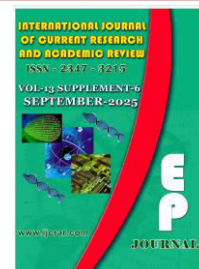


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Common Baking Measurements

1 cup = 250 ml. 1 tbsp. = 15 ml. 1 tsp. = 5 ml. 1 ounce = 28.35 grams Tablespoon (T) = 1/2 ounce = 14.79 ml. Teaspoon (t) = 1/6 ounce = 4.93 ml. Pinch (p) = about 1/8 tsp = (0.03-0.48 ml.) Dash = about 1/8 tbsp = (0.84-1.42 ml.) Cup (C) = 8 ounces (oz.) = 237 ml.

Common Conversions of Measurement Table

Fluid Ounces (fl. oz.)

Cup (c) = 8 fl. oz.

Pint (pt) = 16 fl. oz.

Quart (qt) = 32 fl. oz.

Gallon (gal) = 128 fl. oz.

Each person who measures an unmeasured ingredient is tasked to measure accurately. Check the tools available for dry and wet ingredients and what they commonly measure. Consider cups, measuring cups, liquid measuring cups, spoons, measuring spoons, and kitchen scales. Whether being on the local market or the department store aisle, read labels on every available measuring tool in the kitchen.

Home Diy Projects

The importance of mathematics in home DIY (do-it-yourself) projects cannot be understated. Drawing on subjects such as geometry, algebra, measurement, and arithmetic, these projects have the potential to bring hours of fun, creativity, satisfaction, pride, and joy. A mathematical understanding of space and shape helps with planning and projects. Measurement is vital for ensuring that parts fit together as designed, such as the size of joints or tiles. Designs rely on ratios, including the ratio of a vehicle to the width of a door and the best ratio for an arch to avoid collapsing. Ellipses are used in churches for sound projection. The visual arts rely on geometry and numeracy, such as artists needing to know how to mix paints or maintain perspective. Even a simple drawing involves calculations of ratio, measurement, angles, and estimation.

There are two aspects to home DIY projects. Planning is crucial for everything, including repairing a water leak. Most problems involve producing ideas and repeatedly modeling them mathematically, modifying them until an adequate design is made. It is possible to be able to



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visualize most designs and projects without drawing them on paper. The double sickness of perfectionism makes some designs too complicated for hope to build. Listening to good advice and modifying some plans is suggested, such as the design is simpler and cheaper than the original. Speculating on feasible shapes of objects is commonplace, including speculation on the shape of planets. One project of interest is involving raising the roof of an old building to create more space.

Math will be used to work out how much additional weight of timber and tiles roof beams need to carry, as well as how to strengthen beams or how pillars need to redistribute the weight of walls. Some projects are done with old bikes, an interest pursued for years, including designing and building modifications for them. On one bike, adding a third wheel was interesting and featured modifications such as making a shaft drive and fitting an electric motor. One modification that can be made to cruiser bicycles with their huge handlebars and fork stems is to fit smaller handlebars. However, this involves cutting the fork stem and welding. A project on fitting coasters on children's bikes may be completed. Other simple projects may also be done with clips for curtains or turning metals with a lathe.

Much simpler projects can be done with household items, such as sprinkling salt on chicken or lighting a candle. It is suggested that a series of projects involving simple items like plastic or paper cups can be done, leading to bigger cups needing bridging. Other ideas include porches, tiles, planters, gates, bars, and small houses. Additional considerations can include railings.

Conclusion and Future Research Directions

Mathematics plays a crucial role in human life, contributing to efficiency and resourcefulness. It allows individuals to analyze situations rationally and creatively, enhancing decision-making. The systematic reasoning associated with mathematical thinking positively impacts other areas of life, including philosophy and science. Mathematics, both a science and a language, develops quickly and naturally through education and experience, forming part of personal beliefs and social practices. Mathematical knowledge encompasses a range of concepts, skills, and practices related to the use of numbers, operations, geometry, and mathematical ideas in daily tasks and life planning.



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Currently, there is a large amount of research on the effects of mathematics in our daily life activities. The objective of the present study is to investigate the various activities performed in daily life that require mathematics and illustrate them with examples. This was achieved through a questionnaire filled out by people of different age groups and occupations. Different types of daily life activities were identified and classified according to the mathematical skills required to accomplish them, such as counting, addition or subtraction, multiplication, division, estimation, geometry, percentages and interest, time calculations, sequencing and ordering, and geometry. It was observed that there is a connection between individuals' level of engagement in mathematics activities and their age and academic qualifications.

An effort was made to analyze and summarize the data in tabular form. Mathematical activities performed in everyday life were found to be strongly influenced by variables such as the age and the academic qualification of the activity performers. Young students relied mainly on counting, while elderly people confined themselves to simple arithmetic operations. This way, the understanding of mathematics in daily life, although quite broad, becomes quite vague as it is not essential and cannot go beyond the simple numeric operations learned in school. With education and employment, the use of mathematics becomes more advanced and sophisticated; nevertheless, individuals remained ignorant of mathematics topics learned in higher education. Almost everybody believes mathematics is difficult, and there are many who go to the extent of saying that they hate this subject. At the same time, it is shown that mathematics in everyday life, although not a topic of general awareness, is quite complex and deals with Euclidean geometry and calculus as well. Attention and future research directions are now focused on filling gaps in the present study and addressing the issues raised from its results.

Future research could analyze how daily life activities would be performed in the absence of mathematics or further investigate and summarize these activities by age and/or occupation. The bridge between formal and less formal mathematical practices could be examined as well as its consequences in terms of educational policies. Lastly, methodology addressing and focusing upon mathematics topics learned in higher education could be developed. To sum up, this study reinforces the importance of mathematics in daily life activities and quality of life and provides an impetus for further investigation in this field.



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Full Length Article

IJCRAR/FL/76

Edge Cover Number of Coronagraphs and Tensor Product Graphs

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Abstract

The study of edge covering in graph theory plays a fundamental role in understanding network optimization, resource allocation, and structural analysis of interconnection networks. An edge cover of a graph G is a set of edges such that every vertex of G is incident with at least one edge in the set, and the edge covering number $\beta'(G)$, $\beta'(G)$ is the minimum cardinality of such a set. In this paper, we investigate the edge covering number for two important graph products: the corona product and the tensor product of graphs. For corona product graphs $G \odot H$ we establish bounds and exact values of $\beta'(G \odot H)$, in terms of the parameters of the base graphs G and H . We further explore the edge covering behavior of the tensor product $G \otimes H$, deriving relationships between $\beta'(G \otimes H)$ and the edge covering numbers of the factor graphs. Comparative analysis between these two products reveals how structural properties such as degree distribution, connectivity, and domination interact with covering requirements. The results provide new insights into product graph theory and contribute to potential applications in designing efficient interconnection networks and communication systems.

Keywords: Edge covering , matching, corona graphs, tensor product of graphs

Introduction

Covering problems constitute one of the central themes in graph theory due to their theoretical depth and wide range of applications. Among these, the edge covering problem has been extensively studied for its structural importance and algorithmic relevance. For a given



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graph $G(V,E)$, an edge cover is a subset of edges $C \subseteq E$ such that every vertex of V is incident with at least one edge in C . The smallest cardinality of such a set is known as the edge covering number of G , denoted by $\beta^{\wedge}(G)$. This parameter provides a natural measure of how efficiently edges can be chosen to ensure that no vertex remains isolated from the covering set. The study of edge covering is closely intertwined with other fundamental graph invariants. One of the most celebrated results in this context is the relationship between the edge covering number and the size of a maximum matching. Specifically, for any finite simple graph G without isolated vertices, it holds that $\beta^{\wedge}(G) + \alpha^{\wedge}(G) = |V|$, where $\alpha^{\wedge}(G)$ denotes the matching number of G .

This equality, originally observed in the works of Ore [1] and later elaborated by Gallai [2], reveals the complementary nature of matchings and edge coverings, and forms the theoretical basis for many subsequent investigations. Several researchers have contributed to the development of edge covering theory. Harary [3] provided early foundational results linking covering parameters with domination and independence numbers. Javadi and Omoomi [4] examined edge covers in product graphs, highlighting their role in interconnection networks. More recently, attention has been directed towards generalized versions, such as the edge cover polynomial introduced by Alikhani and Peng [5], which encodes the number of edge covers of various sizes and provides richer structural information about graphs.

From a practical perspective, edge covering arises in network design, where one aims to minimize the number of communication links required to ensure every node is incident with at least one active link. It also finds applications in resource allocation, biological modeling, and task scheduling, where “coverage” of entities with the least number of interactions is desirable. Furthermore, in interconnection networks such as hypercubes, grids, and Mycielskian graphs, the determination of edge covering numbers helps to evaluate redundancy, fault tolerance, and connectivity. Despite the substantial progress, several research gaps remain. For instance, the behavior of edge covering numbers in new families of interconnection networks, generalized graph products, and dynamic network models is not yet fully understood. Similarly, the interplay between edge covering and other covering parameters, such as vertex covering and domination, invites further exploration. These directions motivate the present study, which aims to analyze the edge covering number and its extensions in the context of structured graph classes and network models.



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Preliminaries

In this section, we present some basic definitions, notations, and known results which will be used throughout the paper. All graphs considered here are finite, simple, and undirected. Definition.2.1: Let $G(V,E)$ be a graph with vertex set $V(G)$ and edge set $E(G)$. The order and size of G are denoted by $|V(G)|$ and $|E(G)|$, respectively. For a vertex $v \in V(G)$, the degree of v is denoted by $\deg(v)$. The minimum and maximum degree of G are denoted by $\delta(G)$ and $\Delta(G)$, respectively.

Definition.2.2: A subset $C \subseteq E(G)$ is called an edge cover of G if every vertex $v \in V(G)$ is incident with at least one edge in C . The minimum cardinality of an edge cover is called the edge cover number of G , denoted by $\beta'(G)$. Clearly, if G has no isolated vertices, then $\beta'(G) + \alpha'(G) = |V(G)|$, where $\alpha'(G)$ denotes the matching number of G .

Definition.2.3: The corona product of two graphs G_1 and G_2 , denoted by $G_1 \odot G_2$, is obtained by taking one copy of G_1 and $|V(G_1)|$ copies of G_2 , and then joining each vertex $v_i \in V(G_1)$ to every vertex of the i^{th} copy of G_2 . Corona product graphs exhibit rich combinatorial properties and have been studied with respect to domination, independence, matching, and covering numbers.

Definition.2.4: The tensor product of two graphs G_1 and G_2 , denoted by $G_1 \otimes G_2$, is the graph with vertex set $V(G_1 \otimes G_2) = V(G_1) \otimes V(G_2)$, where two vertices (u,v) and (u',v') are adjacent in $G_1 \otimes G_2$ if and only if $uu' \in E(G_1)$ and $vv' \in E(G_2)$. Tensor product graphs often model parallel architectures and multi-dimensional interconnection networks. Studying edge covering numbers in these networks helps analyze redundancy, fault tolerance, and efficiency of communication links. Moreover, examining their corona and tensor products provides deeper insights into the behavior of covering parameters in large-scale interconnection models. In this paper we investigate the edge cover number for the corona products of graphs and tensor product of graphs.

Main Results

This section focusing on finding the edge cover number of the corona product of various graphs with G , namely cycle, path, complete graph and tensor product of graphs.

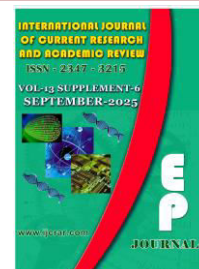


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Lemma 3.1 [1,2,3] Let G be a simple graph with n vertices. Then $\beta^{\wedge}(G) = |V(G)| - \alpha^{\wedge}(G)$

Lemma 3.2 [1,2,3] Let G_1, G_2, G_3 and G_4 be a path, cycle, complete graph and a star graph on n vertices then $\beta^{\wedge}(G_i) = \{(\lfloor n/2 \rfloor, i=1,2,3 @ n-1, i=4)\}$

Theorem 3.3 Let G and H be any graph of order m and n respectively then $\beta^{\wedge}(G \odot H) = \{(m\beta^{\wedge}(H) + \beta^{\wedge}(G), n \text{ is even} @ m\beta^{\wedge}(H), n \text{ is odd})\}$

Proof :

For any graph X with no isolated vertices, the classical relation between the minimum edge cover number $\beta^{\wedge}(X)$ and the maximum matching number $\mu(X)$ is $\beta^{\wedge}(X) = |V(X)| - \mu(X)$, where $\beta^{\wedge}(X)$ denotes the size of a minimum edge-cover of the graph X . This identity comes from the fact that a matching of size μ leaves $|V| - 2\mu$ vertices unmatched; each such vertex requires at least one more edge to cover, and an optimal construction achieves exactly $|V| - \mu$ edges. Now, consider the corona graph $G \odot H$. Its vertex set has size $|V(G \odot H)| = m(1+n)$. Hence $\beta^{\wedge}(G \odot H) = m(1+n) - \mu(G \odot H)$. (1)

Thus, determining $\beta^{\wedge}(G \odot H)$ reduces to computing the maximum matching number $\mu(G \odot H)$. Structure of a maximum matching in $G \odot H$, $G \odot H$ is formed by taking one copy of G (vertices $v_1, v_2, v_3, \dots, v_m$) and for each v_i attaching a copy H_i of H with edges from v_i to all vertices of H_i .

A matching in $G \odot H$ can include: (1) edges in G , (2) edges in each H_i , and (3) edges between v_i and vertices of H_i . Two possible global configurations arise:

Configuration A: Use a maximum matching inside G ($\mu(G)$ edges) and in each H_i ($m\mu(H)$ edges). Total: $\mu_A = \mu(G) + m\mu(H)$.

Configuration B: Match each central vertex v_i to one vertex in H_i (m edges), and also include maximum matchings inside each H_i ($m\mu(H)$). Total: $\mu_B = m + m\mu(H)$.

Thus, $\mu(G \odot H) = \max \{ \mu(G) + m\mu(H), m + m\mu(H) \}$. (2)

Case 1: n odd.

If n is odd, each H_i has at least one unmatched vertex in any maximum matching. Therefore, every v_i can be matched with such an unmatched vertex, giving $\mu(G \odot H) = m(\mu(H) + 1)$



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Substituting into (1), $\beta^{\wedge}(G \odot H) = m(1+n) - m(\mu(H)+1) = m(n - \mu(H)) = m\beta^{\wedge}(H)$.

Case 2: n even.

If n is even, each H_i can have a perfect matching. In this case, matching v_i to a vertex of H_i does not always improve the total. Thus, the optimal strategy is Configuration A: $\mu(G \odot H) = \mu(G) + m\mu(H)$. Substituting into (1), $\beta^{\wedge}(G \odot H) = m(1+n) - (\mu(G) + m\mu(H)) = \beta^{\wedge}(G) + m\beta^{\wedge}(H)$. Hence, $\beta^{\wedge}(G \odot H) = \{(m\beta^{\wedge}(H) + \beta^{\wedge}(G), n \text{ is even} @ m\beta^{\wedge}(H), n \text{ is odd})\}$

Theorem 3.4:

Let G be a non-bipartite graph with $|V(G)| = m$ and matching number $v(G)$. Let P_n be the path on n vertices. Then the edge covering number of the tensor product $G \otimes P_n$ satisfies:

- (i) $\beta^{\wedge}(G \otimes P_n) = mn - v(G \otimes P_n)$.
- (ii) Bounds: $mn - \min\{v(G)n, m\lfloor n/2 \rfloor\} \leq \beta^{\wedge}(G \otimes P_n) \leq mn - v(G)\lfloor n/2 \rfloor$.
- (iii) If $v(G)n \leq m\lfloor n/2 \rfloor$ and $v(G \otimes P_n) = v(G)n$ then $\beta^{\wedge}(G \otimes P_n) = n(m - v(G))$.
- (iv) If $m\lfloor n/2 \rfloor \leq v(G)n$ and $v(G \otimes P_n) = m\lfloor n/2 \rfloor$, then $\beta^{\wedge}(G \otimes P_n) = m\lfloor n/2 \rfloor$.

Proof.

For any graph X , the edge covering number is given by $\beta^{\wedge}(X) = |V(X)| - v(X)$, where $v(X)$ is the size of a maximum matching of X . Since $|V(G \otimes P_n)| = mn$, we have $\beta^{\wedge}(G \otimes P_n) = mn - v(G \otimes P_n)$.

To bound $v(G \otimes P_n)$, observe that a matching in G and a matching in P_n together induce a matching in the tensor product. Hence $v(G \otimes P_n) \geq v(G)v(P_n) = v(G)\lfloor n/2 \rfloor$.

On the other hand, each vertex in G can be matched at most n times, and each vertex in P_n at most m times. Thus $v(G \otimes P_n) \leq \min\{v(G)n, m\lfloor n/2 \rfloor\}$.

Combining these gives the stated bounds for $\beta^{\wedge}(G \otimes P_n)$.

In the case where $v(G)n \leq m\lfloor n/2 \rfloor$ and the lower bound is attained, we obtain $\beta^{\wedge}(G \otimes P_n) = n(m - v(G))$. Similarly, if $m\lfloor n/2 \rfloor \leq v(G)n$ and equality holds, then $\beta^{\wedge}(G \otimes P_n) = m\lfloor n/2 \rfloor$.

These results serve as fundamental tools in analyzing the edge cover numbers of corona product and tensor product graphs derived from interconnection networks.



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Applications and Implementation

The edge covering problem is not only of theoretical interest but also has significant practical applications in diverse fields. Since an edge cover ensures that every vertex is incident with at least one selected edge, the concept naturally models situations where every entity must be connected, monitored, or served by a resource with minimal redundancy.

Applications: In computer and telecommunication networks, minimizing the number of active links while ensuring every node is connected is equivalent to finding an edge cover. This has applications in energy-efficient routing, link redundancy analysis, and backbone design. Edge covering can model scenarios where each resource (edge) must be assigned so that all users (vertices) are served. Examples include assigning tasks to processors or allocating machines to jobs in manufacturing systems. In biological networks such as protein-protein interaction graphs, edge covers can represent minimal sets of interactions required to ensure that every protein participates in at least one interaction. Similarly, in social networks, edge covering can model team formation or information dissemination. Edge covering corresponds to assigning tasks (edges) such that all workers or machines (vertices) are involved. This is particularly useful in bipartite graphs where one set represents jobs and the other represents machines. In parallel and distributed systems, networks such as hypercubes, grids, and Mycielskian graphs are used to model processor interconnections. Studying the edge cover number in such networks helps in analyzing fault tolerance, load balancing, and the minimum communication overhead required to maintain connectivity. Role in polynomial invariants such as the edge cover polynomial, which encodes structural properties of graphs.

Implementation:

The problem of computing the edge cover number can be efficiently solved using algorithms related to maximum matching. Edmonds' Blossom Algorithm provides a polynomial-time method for computing maximum matchings in general graphs, thereby enabling the computation of edge covers. For structured networks such as hypercubes, grids, and product graphs, recursive and constructive methods can be implemented to determine edge covering numbers without relying on general-purpose algorithms. In tensor product graphs, the edge covering number is related to coverings in the factor graphs. Graph theory software such



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as SageMath, NetworkX (Python), and Macaulay can be used to compute edge covering numbers and simulate applications in large-scale networks. These tools implement efficient maximum matching algorithms that can be adapted for edge cover computations[6].

Conclusion

The study of edge covering numbers in graph products such as the corona product and the tensor product highlights the interplay between structural properties of the constituent graphs and their combined behavior. For corona graphs, the edge covering number is strongly influenced by the replication of subgraphs around each vertex, leading to results that directly connect the edge covering number of the corona to those of the factor graphs. In contrast, tensor product graphs demonstrate a more intricate dependency, where the presence of edges depends on adjacency in both factor graphs, making their edge covering number sensitive to degrees and edge distributions of the components.

Open Problem

While the edge covering number of corona graphs and tensor product graphs has been determined or bounded in several cases, many questions remain open. One significant direction is the characterization of the edge cover polynomial for these product graphs.

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Full Length Article

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Takayasu Arteritis vs. Hypertension: Detecting Rare Diseases from Symptom Overlap

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Abstract

Owing to their low prevalence, genetic complexity, and symptom overlap with common observable conditions, rare diseases present significant diagnostic challenges. Takayasu Arteritis (TA), a rare inflammatory vascular disease, is often misdiagnosed as Hypertension because both share symptoms like elevated blood pressure and migraines etc. This study introduces graph theory to model symptom-disease graphs, integrating patient history, clinical reports, and medical case studies. Considering degree centrality, community detection, and shortest-path problems, the research identifies both overlapping and distinct symptom patterns. Outcomes are conveyed using overlap percentages, centrality scores, and clustering, which quantify similarities while also isolating unique diagnostic markers for TA. Herein, we present that graph-based approaches can significantly support healthcare providers in improving diagnostic accuracy and patient care for rare diseases.

Keywords: Rare Diseases, Takayasu Arteritis, Hypertension, Symptom-Disease graphs.

Introduction

Rare diseases are infamously difficult to diagnose, as their low prevalence and overlapping symptoms often mimic those of common conditions. Takayasu Arteritis (TA), a rare inflammatory disorder of large blood vessels, is a prime example, commonly misdiagnosed as Hypertension because both share symptoms such as high blood pressure, dizziness, and headaches[2]. These diagnostic challenges can cause serious delays in treatment, leading to severe outcomes including vascular damage and organ failure.



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To address this challenge, this study introduces a graph-theoretical framework to model patient, symptom, and disease relationships. A multilayer graph is constructed where vertices represent patients (labelled by age and gender), symptoms, and diseases (TA or Hypertension), while edges representing observed associations between them. The dataset was curated to separate unique and overlapping symptoms, allowing the network to highlight both shared and disease-specific markers. This structure facilitated clear visualization of connections and efficient computation of network metrics, including degree centrality, community detection (greedy modularity), and shortest-path measures.

Conventional diagnostic methods rely mostly on clinical judgment and isolated tests, which may fail to capture the complex interplay of symptoms across patients. Graph theory and network analysis provide a more systematic approach, enabling the discovery of nuanced patterns and distinctive markers that traditional methods might overlook. In this article, the multilayer symptom-disease network is applied to examine overlaps and unique indicators between TA and Hypertension, with the aim of enhancing differential diagnosis, offering clearer clinical insights, and supporting healthcare professionals in managing rare diseases.

Patient Records and Symptom Patterns

A structured dataset was extracted from published case reports and clinical studies involving individuals diagnosed with Takayasu Arteritis (TA) or Hypertension. The dataset included patient age, gender, presenting symptoms (e.g., headache, hypertension, dizziness), and final diagnoses. In total, data from 20 patients were collected: 10 with TA and 10 with Hypertension. This covers 37 distinct symptoms. The statistics summarized in Table 1 (b) are calculated from the Dataset compiled by extracting patient demographics and clinical features from some of the published sources [3, 7] shown in Table 1 (a).

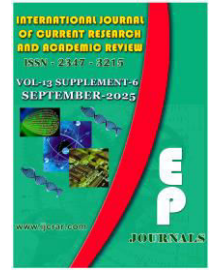


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Patient ID	Age	Gender	Final Diagnosis
H1	69	Female	Hypertension
H2	17	Male	Hypertension
H3	67	Female	Hypertension
H4	33	Female	Hypertension
H5	46	Male	Hypertension
H6	45	Female	Hypertension
H7	57	Male	Hypertension
H8	60	Female	Hypertension
H9	80	Male	Hypertension
H10	70	Male	Hypertension
TA1	37	Male	Takayasu Arteritis
TA2	26	Male	Takayasu Arteritis
TA3	16	Female	Takayasu Arteritis
TA4	26	Female	Takayasu Arteritis
TA5	54	Female	Takayasu Arteritis
TA6	18	Female	Takayasu Arteritis
TA7	26	Male	Takayasu Arteritis
TA8	48	Female	Takayasu Arteritis
TA9	22	Female	Takayasu Arteritis
TA10	17	Female	Takayasu Arteritis

(a)

Statistic	Value
Total Patients	20
Hypertension Patients	10
Takayasu Arteritis Patients	10
Average Age (All)	41.7 years
Average Age (Hypertension)	54.4 years
Average Age (TA)	29.0 years
Female Patients	12 (60%)
Male Patients	8 (40%)

(b)

Table 1: (a) Patient demographics and final diagnoses extracted from case reports and clinical studies (b) Descriptive statistics of the patients

The average age of all patients was 41.7 years, with TA patients averaging younger (29 years) compared to Hypertension patients (54.4 years). The cohort was predominantly female (60%). Despite the shared symptoms across both groups, certain features appeared exclusively in the TA group, including absent pulse, limb claudication, and aortic aneurysm. These unique markers may serve as important diagnostic indicators for distinguishing TA[6] from Hypertension.



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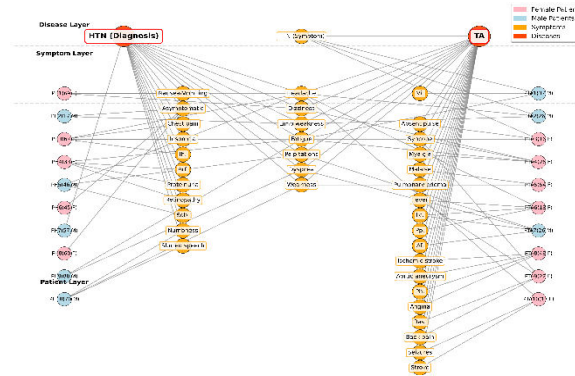


Figure 1: Patient-Symptom-Disease Relation

Graphical Representation of Clinical Data

A multilayer graph was constructed to represent the relationships among patients, symptoms, and diseases. Each patient, symptom, and disease was modelled as a vertex, with edges connecting patients to their reported symptoms and symptoms to the corresponding diagnosis [1, 5]. This design reflects real-world clinical associations. The final graph consisted of 20 patient vertices, 37 symptom vertices, and 2 disease vertices.

The graph shown in Figure 1 provides a clear overview of symptom distributions across the two conditions. Patients with Hypertension were positioned on the left side of the layout, those with Takayasu Arteritis on the right, and symptoms in the central region. Unique symptoms appeared closer to their respective disease vertices, while shared symptoms clustered between them. Vertex shapes and colours distinguished categories such as patient sex, symptom type, and disease class. This multilayer structure emphasizes both overlaps and distinctive features, effectively capturing the complexity of real-world differential diagnosis in a visual and analytical framework.

Degree Centrality Analysis

Degree centrality is a network measure that counts the number of direct connections (edges) a vertex has with other vertices. It quantifies how well connected or important a vertex is within a graph. Formally, for a vertex v in a graph with n vertices, its normalized degree



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centrality is the number of connections divided by the maximum possible connections $n-1$, resulting in a value between 0 and 1[7]. These degree centrality metrics indicated key insights into the prominence of symptoms and diseases within the patient-symptom-disease graph. The TA disease vertex had the highest degree centrality score (0.448), followed by Hypertension (0.328), underscoring their roles as major hubs in the graph. Frequently reported symptoms such as headache and fatigue showed moderate-to-high degree centrality values (~ 0.138), indicating their recurring presence across multiple patients. These values are tabulated in Table 2.

Node	Degree Centrality	Description
TA (Disease)	0.448	Takayasu Arteritis diagnosis
HTN (Diagnosis)	0.328	Hypertension diagnosis
Headache	0.138	Common symptom
Fatigue	0.138	Common symptom
Dizziness	0.069	Common symptom
Limb weakness	0.069	Moderate symptom
Palpitations	0.069	Moderate symptom
Absent pulse	0.034	Rare, TA-specific symptom
Ischemic stroke	0.034	Rare, TA-specific symptom
Aortic aneurysm	0.034	Rare, TA-specific symptom
Syncope	0.051	TA-related symptom
Fever	0.051	TA-related symptom

Table 2: Node Degree Centrality - Diagnoses and Symptom Links

Moderate-scoring symptoms such as dizziness, limb weakness, and palpitations acted as bridges between patient groups but were not universally present. In contrast, low centrality symptoms which includes absent pulses, ischemic stroke, and aortic aneurysm were rare but clinically significant, as they were strongly associated with TA. This highlights that although low centrality values are uncommon, they can indicate highly specific diagnostic markers. For patient vertices, centrality values scaled with the number of symptoms reported, reflecting the clinical complexity of individual cases. Overall, degree centrality proved to be an effective measure in distinguishing common versus disease-specific symptoms and in clarifying overlaps between TA and Hypertension.

Community Detection Analysis

Community detection using the modularity approach successfully identified five main clusters within the patient-symptom graph, each clearly reflecting distinct clinical phenotypes.

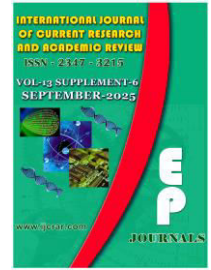


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The first cluster represented Hypertension, comprising the diagnosis vertex, associated patients, and typical symptoms such as fatigue, chest pain, insomnia, and proteinuria, thereby reflecting clinically coherent patterns[6]. The second cluster corresponded to Takayasu Arteritis, containing the TA diagnosis vertex, patients, and hallmark symptoms including fever, ischemic stroke, aortic aneurysm, which emphasized the distinct vascular and systemic features of the disease. A third cluster captured overlap between the two conditions, bringing together symptoms such as limb weakness, absent pulse, and asymptomatic cases, underscoring areas of diagnostic uncertainty. Two smaller clusters-communities 3 to 5 contained unique patient-symptom combinations, such as syncope, seizures, nausea or vomiting, and dizziness, representing atypical or uncommon presentations. Overall, these clusters clearly highlight the utility of community detection in distinguishing disease-specific patterns, identifying areas of overlap, and recognizing a typical case, thus supporting more precise differential diagnosis and significantly enhancing clinical decision-making. See Table 3 for Community detection where each community's core vertices and their characteristic symptom or diagnosis patterns.

Community	Core Vertices	Typical Features
0	HTN (Diagnosis), Fatigue, Chest pain, Insomnia	Hypertension-related
1	TA, Fever, Ischemic stroke, Aortic aneurysm	Takayasu Arteritis-specific
2	Limb weakness, Absent pulse, HTN/TA overlap nodes	Overlapping/ambiguous cases
3 to 5	Unique patients/symptom sets	Isolated or rare combinations

Table 3: Community Detection of Symptom

Shortest Path Detection Analysis

Shortest Path Problem for an unweighted graph is defined by, for a given graph $G=(V,E)$ with vertex set V and edge set E , the shortest path between two vertices v and u in V is the path with the minimum number of edges connecting v to u [1, 5]. It was applied to trace the connections between patients and their diagnosis nodes via reported symptoms. For Hypertension, the paths were generally minimum length which indicates the paths are short and direct, often involving only one or two common symptoms such as headache or fatigue. In contrast, Takayasu Arteritis (TA) diagnostic paths are more complex and varied. While some TA paths are short (two edges), others cases exhibited longer and more complex paths, often requiring rare but critical symptoms - such as ischemic stroke, syncope, or limb claudication - to

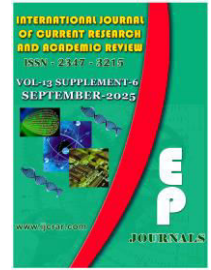


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act as “bridge” vertices leading to the correct diagnosis. The presence of multi-step pathways underscores the diagnostic complexity of TA and highlights the importance of recognizing these specific markers early. A shortest diagnostic path from initial symptom(s) to final diagnosis, showing each patient’s pathway and path length is shown in Table 4. Overall, shortest path analysis illustrates how symptom trajectories can guide and accelerate differential diagnosis, enabling faster recognition of rare conditions compared to more prevalent diseases.

Patient	Diagnosis	Path
PH1 (69, F)	Hypertension	PH1 → Headache → HTN (Diagnosis)
PH1 (69, F)	Takayasu Arteritis	PH1 → Headache → TA
PH6 (45, F)	Hypertension	PH6 → Asymptomatic → HTN (Diagnosis)
PH6 (45, F)	Takayasu Arteritis	PH6 → Asymptomatic → PH2 → Limb weakness → TA
PTA8 (48, F)	Hypertension	PTA8 → Ischemic stroke → TA → Fatigue → HTN (Diagnosis)
PTA8 (48, F)	Takayasu Arteritis	PTA8 → Ischemic stroke → TA

Table 4: Shortest diagnostic paths from initial symptom(s) to final diagnosis

Conclusion

This study showed that graph-based structure can improve the differential diagnosis of Takayasu Arteritis (TA) and Hypertension by modelling patient - symptom - disease relationships. The multilayer graph representing the Patient, Symptom and Disease relationship in this article was generated using Python. Degree centrality highlighted both common and rare but clinically significant symptoms, while community detection revealed disease-specific clusters and areas of overlap. Shortest path problem emphasized the diagnostic complexity of TA compared to the more direct patterns of Hypertension. NetworkX built-in algorithms were used for degree centrality, community detection (greedy modularity), and shortest path analyses, with results exported to CSV for reporting.

The findings strongly suggest that multilayer graph models can serve as powerful and reliable decision-support tools for rare diseases, significantly reducing diagnostic delays and ultimately improving patient outcomes. Although limited by small curated datasets, future validation with larger clinical data and integration with machine learning could further enhance predictive accuracy.



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Full Length Article

IJCRAR/FL/78

Adaptive Inventory Optimization for Social Media-Driven Demand Using Heptagonal Fuzzy EOQ and AI Forecasting

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Abstract

This paper presents a hybrid inventory optimization model designed for markets influenced by rapid social-media trends. The approach integrates the fuzzy Economic Order Quantity (EOQ) framework with Heptagonal Fuzzy Numbers (HFNs) to capture uncertainty in demand and costs, while Artificial Intelligence (AI) techniques are employed to forecast demand surges in real time. A case study on Matcha tea, a globally trending product, illustrates the effectiveness of the model. The results show that the fuzzy-AI framework provides more reliable stock recommendations than the classical EOQ model, particularly under volatile conditions. By combining uncertainty modeling with predictive analytics, the proposed method offers a practical decision-support tool for businesses facing unpredictable, trend-driven markets.

Keywords: Fuzzy EOQ, Heptagonal fuzzy number, Artificial intelligence, Inventory optimization, Social media-driven demand

Introduction

The rapid growth of social media has significantly altered consumer behavior, often creating sudden and unpredictable shifts in product demand. Viral posts, influencer endorsements, and trending hashtags can trigger demand surges within hours, leaving



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conventional inventory systems unable to respond effectively. Traditional Economic Order Quantity (EOQ) models, which rely on stable demand assumptions and historical data, are increasingly insufficient for markets shaped by these fast-moving trends.

One example is Matcha tea, which has gained worldwide popularity due to its recognized health benefits such as high antioxidant content, stress reduction, and cognitive support. Beyond wellness, online promotion and lifestyle branding have amplified its appeal, creating global spikes in demand. Such cases highlight the vulnerability of supply chains when unexpected social media-driven demand meets limited production capacity.

To address these challenges, this study proposes an integrated framework that combines fuzzy EOQ modelling with Artificial Intelligence (AI)-based demand forecasting. Heptagonal Fuzzy Numbers (HFNs) are employed to represent uncertain parameters such as demand, ordering cost, and holding cost, while AI tools analyse real-time data streams to detect and predict market fluctuations. By merging uncertainty modelling with predictive analytics, the framework provides a more adaptive and resilient inventory planning approach for trend-sensitive products.

Definitions and Preliminaries

Definition 2.1 (Fuzzy Set): A Fuzzy Set A in a union of disclosure X is characterized by a membership function $\mu_A(x): X \rightarrow [0,1]$, which assigns to each element of $x \in X$ a membership grade in the interval $[0,1]$.

- if $\mu_A(x)=1$, x fully belongs to A .
- if $\mu_A(x)=0$, x does not belong to A .
- intermediate values represent partial membership.

Definition 2.2 (Fuzzy numbers): A fuzzy set $\tilde{A}$ is a fuzzy number iff (i) For all $\alpha \in (0,1]$ the α cut sets A_α is a convex set (ii) $\mu_{\tilde{A}}$ is a bounded set in R

(iii) $\text{Supp}(\tilde{A})$ is a bounded set in R (iv) The height of $\tilde{A} = \max_{x \in X} \mu_{\tilde{A}}(x) = \omega > 0$.

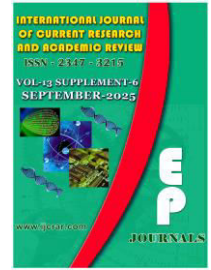


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Definition 2.3 (Heptagonal Fuzzy number): The parametric form of Heptagonal Fuzzy Number is defined as $\tilde{H} = (f_1(r)g_1(t), g_2(t), f_2(r))$ for $r \in [0, k]$ and $t \in [k, 1]$ where $f_1(r)$ and $g_1(t)$

are bounded left continuous non decreasing functions over $[0, \omega_1]$ and $[k, \omega_2]$ respectively, $f_2(r)$ and $g_2(t)$ are bounded left continuous non increasing functions over $[0, \omega_1]$ and $[k, \omega_2]$ respectively and $0 \leq \omega_1 \leq k, k \leq \omega_2 \leq 1$.

The membership function for the heptagonal fuzzy number $\tilde{H} = (h_1, h_2, h_3, h_4, h_5, h_6, h_7; k, \omega)$

$$\mu_{\tilde{H}}(x) = \begin{cases} 0 & \text{for } x < h_1 \\ k \left(\frac{x - h_1}{h_2 - h_1} \right) & \text{for } h_1 \leq x \leq h_2 \\ k + (\omega - k) \left(\frac{x - h_3}{h_4 - h_3} \right) & \text{for } h_2 \leq x \leq h_3 \\ k & \text{for } h_3 \leq x \leq h_4 \\ k + (\omega - k) \left(\frac{x - h_5}{h_6 - h_5} \right) & \text{for } h_4 \leq x \leq h_5 \\ k + (\omega - k) \left(\frac{h_7 - x}{h_6 - h_5} \right) & \text{for } h_5 \leq x \leq h_6 \\ k & \text{for } h_6 \leq x \leq h_7 \\ 0 & \text{for } x \geq h_7 \end{cases}$$

Remark

(i) The above defined heptagonal fuzzy number becomes normal heptagonal fuzzy number if $\omega=1$

(ii) $k=0$ then the heptagonal fuzzy number reduces to triangular fuzzy number (h_3, h_4, h_5) if $k=1$ it reduces to trapezoidal fuzzy number (h_1, h_2, h_6, h_7) .

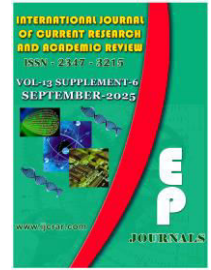


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Definition 2.4 (Economic Order Quantity): It is the order quantity that minimize the total cost (ordering cost + holding cost) $EOQ = \sqrt{(2DS/H)}$

Where:

D: annual demand

S: order cost per order

H: holding cost per unit year

Here D, S, H are modelled as heptagonal fuzzy numbers in fuzzy environment.

Definition 2.5 (Artificial Intelligence (AI) in Inventory forecasting): AI in inventory control refers to the use of machine learning or predictive algorithms to forecast demand, optimize stock levels, and reduce supply chain disruption. AI uses real-time data (social media trends, online sales, sentiment analysis) to identify unexpected rise in demand early.

Model Description

Case Context and Model Justification:

Real world data shows the trending products, especially those are influenced by viral social media, are unpredictable in terms of demand.

Traditional inventory systems lack the adaptability to respond:

- ✓ sudden rise in demand
- ✓ viral influence not visible in past data
- ✓ stockout
- ✓ inaccurate forecasting using crisp historical data alone
- ✓ supply shortages from constrained resources (e.g. pistachios, matcha).

Proposed decision- support inventory model addresses:

- ✓ uses Heptagonal fuzzy number for representing uncertain demand and cost input
- ✓ Artificial Intelligence (AI) for detecting, predicting, and tracking consumer trends
- ✓ Fuzzy EOQ logic for adjusting stock control under uncertainty



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- ✓ Supports inventory decision during trend-driven rapid changes.

Input Case: Real -world scenarios

Case: Matcha-based products (Global health and wellness trend)

Trend trigger- Health & wellness trend #matchafever

Variability category- Gradual but high-volume

Model Frame work:

Step 1: Trend detection and forecasting (AI layer)

- ✓ Indicates the exact trend-related web data's, hashtags, news, and social mentions.
- ✓ Use AI models (e.g. regression, time-series LSTM) to predict potential demand rise.

Step 2: Demand Representation (Fuzzy Layer)

- Represent predicted and historical demand values using Heptagonal Fuzzy Numbers (HFNs)
 $\tilde{D} = (d1, d2, d3, d4, d5, d6, d7)$
- Captures range of low-to-high demand scenarios
- Makes the model adaptive under uncertainty

Step 3: EOQ and Inventory control (Hybrid layer)

- ✓ Apply modified Fuzzy EOQ formula under fuzzy parameters:
- ✓ Fuzzy Demand
- ✓ Fuzzy holding cost
- ✓ Fuzzy ordering cost
- ✓ Calculate fuzzy optimal order quantity and reorder point

Role of HFNs in the mode:

Heptagonal fuzzy number is used to encode the demand instead of single point forecasting to avoid over ordering and under ordering, especially in the case of unpredictable viral trends.

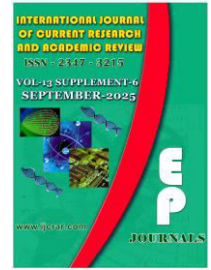


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For example: $\tilde{D}=(a1, a2, a3, a4, a5, a6, a7)$, This model helps various demand levels from minimum (a1) to most plausible(a4) to maximum possible(a7).

Role of AI in the model:

The AI models work as an early detector of trend signals : monitors search engine spikes, social mentions and frequency news. The predicts likely demand surges before the reflect in traditional sales data. It integrates with fuzzy logic layer to adjust inventory decisions.IT ensures the real-time data stream predictions are directly applied to the fuzzy model, allowing dynamic inventory control.

Advantages of this model:

Feature	Advantage
HFN usage	More expressive than triangular or trapezoidal fuzzy numbers, captures fine grained fluctuations.
AI Integration	Allows the system to react to external signals-not just historical data.
Hybrid Architecture	Flexible, scalable and suitable for real-time inventory decision making.

Dual case application tests both trend types 1. impulse- based, 2. Wellness- based

The final output provides:

- ✓ Recommended Order Quantity (fuzzy range)
- ✓ Reorder point (based on trend alert level)
- ✓ Risk-level scoring: High, Medium, or Low based on uncertainty width of HFN

Model overview

Input 1: AI- analyzed data from web trends, social media, sales.

Input 2: Historical sales stored data converted to HFNs to account for uncertainty.



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AI forecast layer: predicts upcoming rise in demand using time series or regression models.

Fuzzy Inventory layer: Applies HFNs to EOQ model to compute optimal order quantity under uncertainty

OUTPUT: Order quantity and Reorder point recommendations with low risk of stockouts.

Proposed Inventory model in crisp environment

CASE: MATCHA GREEN TEA

MODEL NAME: ECONOMIC ORDER QUANTITY(EOQ)-crisp environment

Formula:

$$EOQ = \sqrt{\frac{2DS}{H}}$$

Notations:

D- Annual demand(units/year)

S- Ordering cost per order (₹ or \$)

H- Holding cost per unit per year (₹ or \$)

EOQ- Economic Order Quantity (units)

Assumptions:

- ✓ Demand is known & constant
- ✓ Instantaneous replenishment
- ✓ No stockouts
- ✓ Constant holding and ordering cost

Numerical example:

Consider,



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- ✓ Annual demand(D) = 60,000 units
- ✓ Ordering costs(s)=₹ 2,000 per order
- ✓ Cost of One matcha product =₹500
- ✓ Holding cost rate = 15% of item cost

H= 0.15*500=₹75 per unit/year

Now apply the EOQ formula:

$$EOQ = \sqrt{\frac{2 \cdot 60,000 \cdot 2,000}{75}} = \sqrt{\frac{240,000,000}{75}} = \sqrt{3,200,000} \approx 1788.85$$

Result: To minimize total inventory cost for Matcha tea, the optimal order quantity is 1,789 units per order. Crisp EOQ model applied to the case Matcha tea, EOQ is 1,789

Proposed Inventory model in Fuzzy environment

MODEL NAME: ECONOMIC ORDER QUANTITY(EOQ)-Fuzzy environment

Formula: fuzzy EOQ formula

$$EOQ = \sqrt{(2 \cdot C_o \cdot \tilde{D}) / C_h}$$

Where:

$\tilde{D}$: Fuzzy demand represents HFN

C_o : Ordering cost

C_h : Holding cost (monthly)

Definition of Heptagonal Fuzzy Number (HFN)

A Heptagonal Fuzzy Number is defined as $\tilde{A} = (a_1, a_2, a_3, a_4, a_5, a_6, a_7)$

Where:

a_1 : lower bound with 0 membership

a_2, a_3 : gradual increase

a_4 : peak (membership=1)

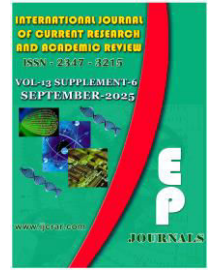


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a5, a6: gradual decrease

a7: upper bound with 0 membership

Case: Matcha green tea

Let the given data

Ordering cost=₹1,800

Holding cost=₹6 per unit per year → ₹0.5 per month

Fuzzy monthly demand = $\tilde{D} = (1400, 1600, 1800, 2000, 2200, 2400, 2600)$

For each $D_j \in \tilde{D}$ we compute EOQ:

$$EOQ_i = \sqrt{\frac{2 \cdot 1800 \cdot D_j}{0.5}}$$

Applying the formula

$$EOQ = \left(\sqrt{\frac{2 \cdot 1800 \cdot 1400}{0.5}}, \sqrt{\frac{2 \cdot 1800 \cdot 1600}{0.5}}, \sqrt{\frac{2 \cdot 1800 \cdot 1800}{0.5}}, \sqrt{\frac{2 \cdot 1800 \cdot 2000}{0.5}}, \right. \\ \left. \sqrt{\frac{2 \cdot 1800 \cdot 2200}{0.5}}, \sqrt{\frac{2 \cdot 1800 \cdot 2400}{0.5}}, \sqrt{\frac{2 \cdot 1800 \cdot 2600}{0.5}} \right)$$

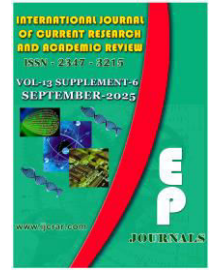


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d_j	computation	EOQ(units)
1400	$\sqrt{\frac{2 \times 1800 \times 1400}{0.5}} = \sqrt{10080000}$	3174.901
1600	$\sqrt{\frac{2 \times 1800 \times 1600}{0.5}} = \sqrt{11520000}$	3394.112
1800	$\sqrt{\frac{2 \times 1800 \times 1800}{0.5}} = \sqrt{12960000}$	3600.000
2000	$\sqrt{\frac{2 \times 1800 \times 2000}{0.5}} = \sqrt{14400000}$	3794.733
2200	$\sqrt{\frac{2 \times 1800 \times 2200}{0.5}} = \sqrt{15840000}$	3979.949
2400	$\sqrt{\frac{2 \times 1800 \times 2400}{0.5}} = \sqrt{17280000}$	4156.921
2600	$\sqrt{\frac{2 \times 1800 \times 2600}{0.5}} = \sqrt{18720000}$	4326.661

$E\tilde{O}QMatch \approx (3174.901, 3394.112, 3600.000, 3794.733, 3979.949, 4156.921, 4326.661)$

Total inventory cost analysis in fuzzy EOQ model

Total inventory cost formula:

$$TC_i = \frac{C_0 \cdot D_i}{Q_i} + \frac{C_h \cdot Q_i}{2}$$



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Where:

TC_i : Total inventory cost at the ith EOQ point

C_o: Ordering cost per order

C_h : holding cost per unit per month

D_i: Monthly demand (from Heptagonal fuzzy Demand $\tilde{D}$)

Q_i: Corresponding EOQ value (from fuzzy EOQ set)

NOW

Given:

Ordering cost: ₹1800

Holding cost: ₹0.5

Fuzzy demand (monthly) $\tilde{D} = (1400, 1600, 1800, 2000, 2200, 2400, 2600)$

EOQ values $\tilde{Q} \approx (3174.9015, 3394.112, 3600.000, 3794.733, 3979.949, 4156.921, 432.661)$

Example calculation (first value):

$$Tc_1 = \frac{1800 \cdot 1400}{3174.901} + \frac{0.5 \cdot 3174.901}{2} = 793.90 + 793.73 = 1587.69$$

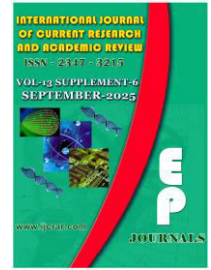


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Cost table:

D _j	EOQ _j	Ordering cost ₹	Holding cost ₹	Total cost ₹
1400	3174.901	793.96	793.73	1587.69
1600	3394.112	848.54	848.53	1697.07
1800	3600.000	900.00	900.00	1800.00
2000	3794.733	949.05	948.68	1897.73
2200	3979.949	995.29	994.99	1990.28
2400	4156.921	1039.11	1039.23	2078.34
2600	4326.661	1081.62	1081.67	2163.29

Defuzzification, Ranking and interpretation of Fuzzy inventory model

Defuzzification:

The centroid-simple average method is used to calculate single representation EOQ value from the Fuzzy set, where when every point in the fuzzy number is considered equally relevant.

$$\text{Defuzzification } EOQ = \frac{a+b+c+d+e+f+g}{7}$$

$$EOQ_{\text{Matcha}} = (3174.9015, 3394.112, 3600.000, 3794.733, 3979.949, 4156.921, 4326.661)$$

$$\text{Defuzzification } EOQ_{\text{Matcha}} = \frac{3174.901+3394.112+3600.000+3794.733+3979.949+4156.921+4326.661}{7}$$



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$$= \frac{26427.28}{7}$$

$$= 3775.33 \text{ units/month}$$

$$= 3775.33 \text{ units/month}$$

Ranking:

$$\begin{aligned} R(E\tilde{O}Q_{\text{Matcha}}) &= \frac{3174.901 + 2(3394.112) + 2(3600.000) + 2(3794.733) + 3979.949 + 4156.921 + 4326.661}{10} \\ &= \frac{37216.112}{10} \\ &= 3721.61 \text{ units/month} \end{aligned}$$

Decision-oriented analysis:

The defuzzification EOQ represents the optimal stock-level, which can be maintain the situations where demand fluctuation occurs

The ranked EOQ supports inventory priority under different situations giving more weight to demand points with higher relevance and centrality.

This ensures:

- ✓ Reduce guesswork in inventory planning
- ✓ Avoid under or overstocking
- ✓ Fast response when demand is higher than usual
- ✓ Ordering cycles with most likely market needs
- ✓ These results give the expected order quantity under uncertain demand caused by social-media trends
- ✓ For Matcha tea, a recommended monthly order is ~ 3721 units

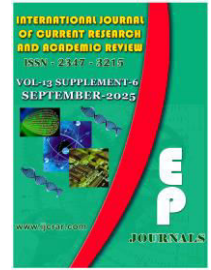


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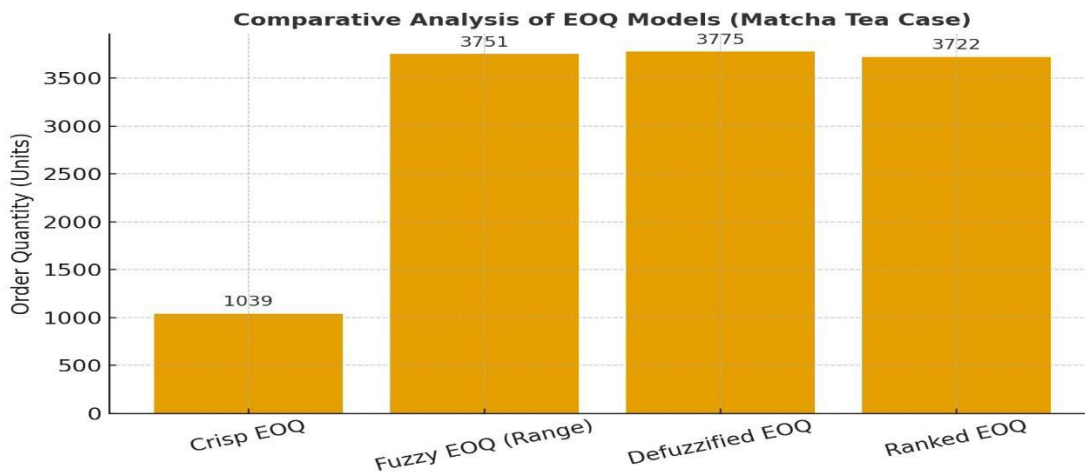
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Comparative analysis and AI forecasting integration

Comparison table:



Case	Crisp EOQ (units)	Fuzzy EOQ range (HFN)	Defuzzified EOQ	Ranked EOQ
Matcha tea	1039.23	3174.901-4326.661	3775.33	3721.61

- Fuzzy EOQ is more realistic for unpredictable markets.
- Crisp EOQ severely underestimates required stock during demand fluctuation
- Defuzzified values guide better monthly procurement decisions.

Role of AI in inventory planning

Artificial intelligence can process the live market signals like social media sentiment, influencer campaigns, consumer purchase spikes, news and media trends. Using the data AI can predict sudden demand shifts, suggest order interval, optimize storage and reorder alert,



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prevent under or over stockage.AI fits into EOQ by providing real-time inputs like updated demand estimates which connect into EOQ model, making the system responsive and adaptive.

Smart inventory decision flow of combining AI and Fuzzy logic:

AI forecast the spike, fuzzy EOQ expands its demand bounds and defuzzifies EOQ increases order quantity automatically preventing future shortage or customer loss.

1. Trend Data Capture – AI collects real-time social media + web signals
2. Pattern prediction-AI forecast short-term demand fluctuation
3. Fuzzy EOQ model input- forecast feed into fuzzy demand model
4. Defuzzification & Ranking-EOQ recommendations adjusted to optimal level
5. Order recommendation issued-App or dashboard notifies stock team with EOQ and timing.

Conclusion:

This study demonstrates that conventional inventory models are inadequate for markets influenced by sudden, trend-driven demand surges. Using Matcha tea as a case example, we developed a hybrid EOQ framework that integrates Heptagonal Fuzzy Numbers (HFNs) for uncertainty representation with Artificial Intelligence (AI) for real-time forecasting. The proposed approach not only accommodates volatile demand patterns but also translates fuzzy estimates into actionable order quantities through defuzzification and ranking techniques. Comparative analysis confirms that the fuzzy-AI model outperforms the classical EOQ method by reducing the risks of both stockouts and excess inventory.

By combining predictive analytics with fuzzy optimization, the model provides inventory managers with a practical decision-support tool for highly dynamic markets. Beyond wellness products, the framework is adaptable to other consumer goods influenced by viral social media trends. Future work may extend this approach to multi-echelon supply chains, dynamic pricing, and integration with automated decision systems, further enhancing resilience and profitability in uncertain market environments.



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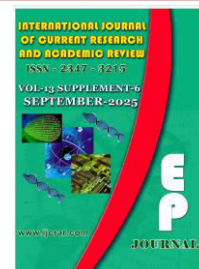


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Full Length Article

IJCRAR/FL/79

Topological indices and Topological polynomials of a few families of graphs

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Abstract

Topological indices, also known as graph invariants, are a single integer that quantifies the topology of a chemical species. Topological indices were first introduced 150 years ago and are still widely used today. According to the literature, over 120 topological indices have been introduced and are now in use. The Wiener index and degree distance index are particularly essential among them. In this work, I will determine Wiener index polynomials and degree distance polynomials for a few graph families, as well as topological indices such as Wiener index and degree distance index.

Keywords: Degree distance polynomial, Octopus graph, Trees, Wiener index, Wiener Polynomial.

Mathematics subject classification: 05C92

Introduction

Graph theory is becoming an increasingly most important tool in various fields, and in particular in many areas of science. The molecular structure of a chemical compound is looked and treated as a graph called chemical graph. Chemical graph server as a convenient model to study and for further investigation of the chemical compound using graph theory techniques. This methodology of study give rises to a new branch of mathematical chemistry called chemical graph theory.

A simple number that can be used to characterize the graph of a molecule is called a graph invariant which is referred as a topological index. Although a variety of graph invariants called topological indices have been around for some 150 years, it is only during the last three decades

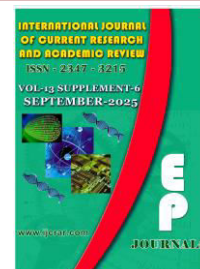


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that they have come with most applications and made this study very popular. There are many classes of chemical indices. The most popular indices are Wiener index [5] and degree distance index [2]. In this paper, the wiener polynomials [4] and degree distance polynomials [3] are determined and using them Wiener index and degree distance index are generated for a few families of graphs.

Preliminaries

Definition: 2.1 Wiener Index [5]

The Wiener index of a graph G is defined as

$$W(G) = \sum_{\{u,v\} \subseteq V(G)} d(u,v)$$

where $d(u,v)$ is the shortest distance between vertices u and v in G .

Definition: 2.2 Degree Distance Index [2]

The degree distance index of a graph G is defined as

$$DD(G) = \sum_{\{u,v\} \subseteq V(G)} [d(u) + d(v)]d(u,v)$$

where $d(u,v)$ is the shortest distance between vertices u and v in G . Also $d(u)$ and $d(v)$ are degrees of vertices u and v in G respectively.

Definition: 2.3 Wiener Polynomial [4]

The Wiener polynomial of a graph G denoted by $W(G;x)$ is defined as

$$W(G;x) = \sum_{\{u,v\} \subseteq V(G)} x^{d(u,v)}$$

where $d(u,v)$ is the shortest distance between vertices u and v in G .



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Definition: 2.4 Degree Distance Polynomial [3]

The degree distance polynomial of a graph G is defined as

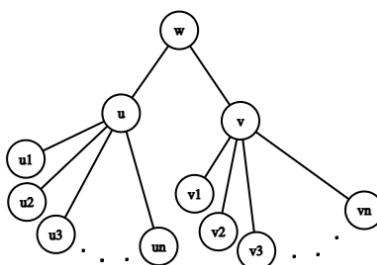
$$DD(G; x) = \sum_{\{u,v\} \subseteq V(G)} x^{[d(u)+d(v)]d(u,v)}$$

where $d(u,v)$ is the shortest distance between vertices u and v in G . Also $d(u)$ and $d(v)$ are degrees of vertices u and v in G respectively.

Definition: 2.5 Tree T_m^*

T_m^* is a tree graph obtained by adding n pendant edges to each pendant vertices of star graph $K_{(1,m)}$. The Cardinality of vertex set is $|V(T_m^*)| = mn + m + 1$ and the Cardinality of edge set is $|E(T_m^*)| = mn + m$.

Example:



Main Results

Theorem: 3.1

The Wiener index and Wiener Polynomial of the graph T_2^* in figure 1 is given by
 $W(T_2^*) = 6n^2 + 10n + 4$ and $W(T_2^*; x) = n^2 x^4 + 2nx^3 + (n^2 + n + 1)x^2 + (2n + 2)x$

Proof:

The Wiener index of a graph T_2^* is given by

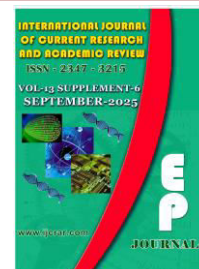


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$$\begin{aligned}
 W(T_2^*) &= d(w, u) + d(w, v) + d(u, v) + \sum_{i=1}^n d(u, u_i) + \sum_{i=1}^n d(v, v_i) + \sum_{i=1}^n d(w, u_i) + \sum_{i=1}^n d(w, v_i) \\
 &\quad + \sum_{i=1}^n d(u, v_i) + \sum_{i=1}^n d(v, u_i) + \left[\sum_{i=2}^n d(u_1, u_i) + \sum_{i=3}^n d(u_2, u_i) + \dots + d(u_{n-1}, u_n) \right] \\
 &\quad + \left[\sum_{i=2}^n d(v_1, v_i) + \sum_{i=3}^n d(v_2, v_i) + \dots + d(v_{n-1}, v_n) \right] + \left[\sum_{i=1}^n d(u_1, v_i) + \sum_{i=1}^n d(u_2, v_i) + \dots + \sum_{i=1}^n d(u_n, v_i) \right] \\
 &= 1 + 1 + 2 + n + n + 2n + 2n + 3n + 3n + 2[(n-1) + (n-2) + \dots + 1] \\
 &\quad + 2[(n-1) + (n-2) + \dots + 1] + (4n + 4n + \dots + 4n) \\
 &= 4 + 12n + 2 \left[\frac{(n-1)n}{2} \right] + 2 \left[\frac{(n-1)n}{2} \right] + n(4n) \\
 W(T_2^*) &= 6n^2 + 10n + 4
 \end{aligned}$$

The Wiener polynomial of a graph T_2^* is given by

$$\begin{aligned}
 W(T_2^*; x) &= x^{d(w,u)} + x^{d(w,v)} + x^{d(u,v)} + \sum_{i=1}^n x^{d(u,u_i)} + \sum_{i=1}^n x^{d(v,v_i)} + \sum_{i=1}^n x^{d(w,u_i)} + \sum_{i=1}^n x^{d(w,v_i)} \\
 &\quad + \sum_{i=1}^n x^{d(u,v_i)} + \sum_{i=1}^n x^{d(v,u_i)} + \left[\sum_{i=2}^n x^{d(u_1,u_i)} + \sum_{i=3}^n x^{d(u_2,u_i)} + \dots + x^{d(u_{n-1},u_n)} \right] \\
 &\quad + \left[\sum_{i=2}^n x^{d(v_1,v_i)} + \sum_{i=3}^n x^{d(v_2,v_i)} + \dots + x^{d(v_{n-1},v_n)} \right] + \left[\sum_{i=1}^n x^{d(u_1,v_i)} + \sum_{i=1}^n x^{d(u_2,v_i)} + \dots + \sum_{i=1}^n x^{d(u_n,v_i)} \right] \\
 &= x^1 + x^1 + x^2 + nx^1 + nx^1 + nx^2 + nx^2 + nx^3 + nx^3 + [(n-1)x^2 + (n-2)x^2 + \dots + x^2] \\
 &\quad + [(n-1)x^2 + (n-2)x^2 + \dots + x^2] + (nx^4 + nx^4 + \dots + nx^4) \\
 &= 2x + x^2 + 2nx + 2nx^2 + 2nx^3 + x^2 \left[\frac{(n-1)n}{2} \right] + x^2 \left[\frac{(n-1)n}{2} \right] + n^2 x^4 \\
 W(T_2^*; x) &= n^2 x^4 + 2nx^3 + (n^2 + n + 1)x^2 + (2n + 2)x
 \end{aligned}$$

Theorem: 3.2

The degree distance index and degree distance polynomial of the graph T_2^* in figure 1 is given by

$$DD(T_2^*) = 20n^2 + 30n + 10 \text{ and}$$

$$DD(T_2^*; x) = 2nx^{3n+6} + 2nx^{n+2} + x^{4n+4} + 2x^{n+3} + n^2 x^8 + 2nx^6 + n^2 x^4 - nx^4.$$

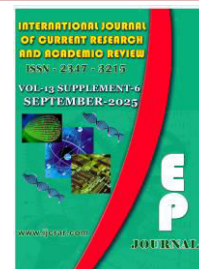


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Proof:

The degree distance index of a graph T_2^* is given by

$$\begin{aligned}
 DD(T_2^*) &= [d(w) + d(u)]d(w, u) + [d(w) + d(v)]d(w, v) + [d(u) + d(v)]d(u, v) \\
 &+ \sum_{i=1}^n [d(u) + d(u_i)]d(u, u_i) + \sum_{i=1}^n [d(v) + d(v_i)]d(v, v_i) + \sum_{i=1}^n [d(w) + d(u_i)]d(w, u_i) \\
 &+ \sum_{i=1}^n [d(w) + d(v_i)]d(w, v_i) + \sum_{i=1}^n [d(u) + d(v_i)]d(u, v_i) + \sum_{i=1}^n [d(v) + d(v_i)]d(v, v_i) \\
 &+ \left[\sum_{i=2}^n [d(u_1) + d(u_i)]d(u_1, u_i) + \sum_{i=3}^n [d(u_2) + d(u_i)]d(u_2, u_i) + \dots + [d(u_{n-1}) + d(u_n)]d(u_{n-1}, u_n) \right] \\
 &+ \left[\sum_{i=2}^n [d(v_1) + d(v_i)]d(v_1, v_i) + \sum_{i=3}^n [d(v_2) + d(v_i)]d(v_2, v_i) + \dots + [d(v_{n-1}) + d(v_n)]d(v_{n-1}, v_n) \right] \\
 &+ \left[\sum_{i=1}^n [d(u_1) + d(v_i)]d(u_1, v_i) + \sum_{i=1}^n [d(u_2) + d(v_i)]d(u_2, v_i) + \dots + \sum_{i=1}^n [d(u_n) + d(v_i)]d(u_n, v_i) \right] \\
 &= (n+3) + (n+3) + (4n+4) + n(n+2) + n(n+2) + 6n + 6n + n(3n+6) + n(3n+6) \\
 &\quad + [(n-1)4 + (n-2)4 + \dots + 4] + [(n-1)4 + (n-2)4 + \dots + 4] + [8n + 8n + \dots + 8n] \\
 &= 8n^2 + 34n + 10 + 4 \left[\frac{(n-1)n}{2} \right] + 4 \left[\frac{(n-1)n}{2} \right] + n(8n) \\
 &= 20n^2 + 30n + 10
 \end{aligned}$$

$$DD(T_2^*) = 20n^2 + 30n + 10$$

The degree distance polynomial of a graph T_2^* is given by

$$\begin{aligned}
 DD(T_2^*; x) &= x^{[d(w)+d(u)]d(w,u)} + x^{[d(w)+d(v)]d(w,v)} + x^{[d(u)+d(v)]d(u,v)} \\
 &+ \sum_{i=1}^n x^{[d(u)+d(u_i)]d(u,u_i)} + \sum_{i=1}^n x^{[d(v)+d(v_i)]d(v,v_i)} + \sum_{i=1}^n x^{[d(w)+d(u_i)]d(w,u_i)} \\
 &+ \sum_{i=1}^n x^{[d(w)+d(v_i)]d(w,v_i)} + \sum_{i=1}^n x^{[d(u)+d(v_i)]d(u,v_i)} + \sum_{i=1}^n x^{[d(v)+d(v_i)]d(v,v_i)} \\
 &+ \left[\sum_{i=2}^n x^{[d(u_1)+d(u_i)]d(u_1,u_i)} + \sum_{i=3}^n x^{[d(u_2)+d(u_i)]d(u_2,u_i)} + \dots + x^{[d(u_{n-1})+d(u_n)]d(u_{n-1},u_n)} \right] \\
 &+ \left[\sum_{i=2}^n x^{[d(v_1)+d(v_i)]d(v_1,v_i)} + \sum_{i=3}^n x^{[d(v_2)+d(v_i)]d(v_2,v_i)} + \dots + x^{[d(v_{n-1})+d(v_n)]d(v_{n-1},v_n)} \right] \\
 &+ \left[\sum_{i=1}^n x^{[d(u_1)+d(v_i)]d(u_1,v_i)} + \sum_{i=1}^n x^{[d(u_2)+d(v_i)]d(u_2,v_i)} + \dots + \sum_{i=1}^n x^{[d(u_n)+d(v_i)]d(u_n,v_i)} \right] \\
 &= x^{(n+3)} + x^{(n+3)} + x^{(4n+4)} + nx^{(n+2)} + nx^{(n+2)} + nx^6 + nx^6 + nx^{(3n+6)} + nx^{(3n+6)} \\
 &\quad + [(n-1)x^4 + (n-2)x^4 + \dots + x^4] + [(n-1)x^4 + (n-2)x^4 + \dots + x^4] + n(nx^8) \\
 &= 2x^{(n+3)} + x^{(4n+4)} + 2nx^{(n+2)} + 2nx^6 + 2nx^{(3n+6)} + x^4 \left[\frac{(n-1)n}{2} \right] + x^4 \left[\frac{(n-1)n}{2} \right] + n^2x^8 \\
 DD(T_2^*; x) &= 2nx^{3n+6} + 2nx^{n+2} + x^{4n+4} + 2x^{n+3} + n^2x^8 + 2nx^6 + n^2x^4 - nx^4
 \end{aligned}$$

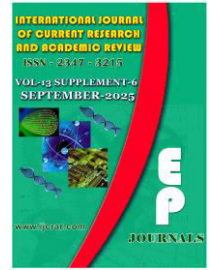


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Observation: 3.3

The above theorems satisfies the properties as follows

- (i) The coefficient of x in $W(T_2^*; x) = (2n + 2)$ is equal to the cardinality of edge set $|E(T_2^*)|$
- (ii) $W(T_2^*; 1) = \binom{|V(T_2^*)|}{2} = \binom{2n+3}{2} = \frac{(2n+3)(2n+2)}{1 \times 2} = 2n^2 + 5n + 3$
- (iii) $DD(T_2^*; 1) = \binom{|V(T_2^*)|}{2} = \binom{2n+3}{2} = \frac{(2n+3)(2n+2)}{1 \times 2} = 2n^2 + 5n + 3$
- (iv) $\frac{d}{dx}(W(T_2^*; x))$ at $x = 1$ is $W(T_2^*) = 6n^2 + 10n + 4$
- (v) $\frac{d}{dx}(DD(T_2^*; x))$ at $x = 1$ is $DD(T_2^*) = 20n^2 + 30n + 10$

Theorem: 3.4

The Wiener index and Wiener polynomial of the graph T_m^* defined in 2.5 is given by

$W(T_m^*) = m^2(2n^2 + 3n + 1) - m(n^2 + n)$ and

$$W(T_m^*; x) = \left(\frac{m^2n^2 - mn^2}{2}\right)x^4 + (m^2n - mn)x^3 + \left(\frac{m^2 + mn^2 - m + mn}{2}\right)x^2 + (mn + m)x.$$

Proof:

The Wiener index of the graph T_m^* is given by

$$\begin{aligned} W(T_m^*) = & \sum_{i=1}^m d(u, v_i) + \left[\sum_{i=2}^m d(v_1, v_i) + \sum_{i=3}^m d(v_2, v_i) + \dots + d(v_{m-1}, v_m) \right] \\ & + \left[\sum_{i=1}^n d(u, w_i) + \sum_{i=1}^n d(u, x_i) + \dots + \sum_{i=1}^n d(u, z_i) \right] \\ & + \left\{ \left[\sum_{i=1}^n d(v_1, w_i) + \sum_{i=1}^n d(v_1, x_i) + \dots + \sum_{i=1}^n d(v_1, z_i) \right] \right. \\ & + \left[\sum_{i=1}^n d(v_2, w_i) + \sum_{i=1}^n d(v_2, x_i) + \dots + \sum_{i=1}^n d(v_2, z_i) \right] + \dots \\ & \left. + \left[\sum_{i=1}^n d(v_m, w_i) + \sum_{i=1}^n d(v_m, x_i) + \dots + \sum_{i=1}^n d(v_m, z_i) \right] \right\} \end{aligned}$$



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$$\begin{aligned}
 & + \left\{ \left[\sum_{i=2}^n d(w_1, w_i) + \sum_{i=3}^n d(w_2, w_i) + \dots + d(w_{n-1}, w_n) \right] \right. \\
 & \quad + \left[\sum_{i=2}^n d(x_1, x_i) + \sum_{i=3}^n d(x_2, x_i) + \dots + d(x_{n-1}, x_n) \right] + \dots \\
 & \quad \left. + \left[\sum_{i=2}^n d(z_1, z_i) + \sum_{i=3}^n d(z_2, z_i) + \dots + d(z_{n-1}, z_n) \right] \right\} \\
 & + \left\{ \left(\left[\sum_{i=1}^n d(w_1, x_i) + \sum_{i=1}^n d(w_2, x_i) + \dots + \sum_{i=1}^n d(w_n, x_i) \right] \right. \right. \\
 & \quad \left. + \left[\sum_{i=1}^n d(w_1, y_i) + \sum_{i=1}^n d(w_2, y_i) + \dots + \sum_{i=1}^n d(w_n, y_i) \right] \right. \\
 & \quad \left. + \dots + \left[\sum_{i=1}^n d(w_1, z_i) + \sum_{i=1}^n d(w_2, z_i) + \dots + \sum_{i=1}^n d(w_n, z_i) \right] \right) \\
 & \quad + \left(\left[\sum_{i=1}^n d(x_1, y_i) + \sum_{i=1}^n d(x_2, y_i) + \dots + \sum_{i=1}^n d(x_n, y_i) \right] \right. \\
 & \quad \left. + \dots + \left[\sum_{i=1}^n d(x_1, z_i) + \sum_{i=1}^n d(x_2, z_i) + \dots + \sum_{i=1}^n d(x_n, z_i) \right] \right) + \dots \Big\} \\
 & = m + [(m-1)2 + (m-2)2 + \dots + 2] + [2n + 2n + \dots + 2n]m \text{ times} \\
 & + \{[n + (3n + 3n + \dots + 3n)(m-1) \text{ times}] + [n + (3n + 3n + \dots + 3n)(m-1) \text{ times}] + \dots \\
 & + [(3n + 3n + \dots + 3n)(m-1) \text{ times} + n]\} \\
 & + [(n^2 - n) + (n^2 - n) + \dots + (n^2 - n)]m \text{ times} + [(m-1) + (m-2) + \dots + 1]4n^2 \\
 & = m + 2 \left(\frac{(m-1)m}{2} \right) + 2mn + mn + [((m-1)3n + (m-1)3n + \dots + (m-1)3n)m \text{ times}] \\
 & + m(n^2 - n) + \left[\left(\frac{(m-1)m}{2} \right) \right] 4n^2 \\
 & = m + m^2 - m + 3mn + 3mn(m-1) + m(n^2 - n) + 2mn^2(m-1) \\
 & W(T_m^*) = m^2(2n^2 + 3n + 1) - m(n^2 + n)
 \end{aligned}$$

The Wiener polynomial of the graph T_m^* is given by

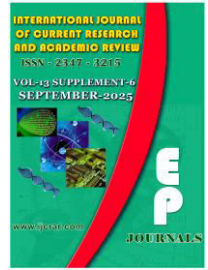


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$$\begin{aligned}
 W(T_2^*; x) = & \sum_{i=1}^m x^{d(u, v_i)} + \left[\sum_{i=2}^m x^{d(v_1, v_i)} + \sum_{i=3}^m x^{d(v_2, v_i)} + \dots + x^{d(v_{m-1}, v_m)} \right] \\
 & + \left[\sum_{i=1}^n x^{d(u, w_i)} + \sum_{i=1}^n x^{d(u, x_i)} + \dots + \sum_{i=1}^n x^{d(u, z_i)} \right] \\
 & + \left\{ \left[\sum_{i=1}^n x^{d(v_1, w_i)} + \sum_{i=1}^n x^{d(v_1, x_i)} + \dots + \sum_{i=1}^n x^{d(v_1, z_i)} \right] \right. \\
 & + \left[\sum_{i=1}^n x^{d(v_2, w_i)} + \sum_{i=1}^n x^{d(v_2, x_i)} + \dots + \sum_{i=1}^n x^{d(v_2, z_i)} \right] + \dots \\
 & \left. + \left[\sum_{i=1}^n x^{d(v_m, w_i)} + \sum_{i=1}^n x^{d(v_m, x_i)} + \dots + \sum_{i=1}^n x^{d(v_m, z_i)} \right] \right\} \\
 & + \left\{ \left[\sum_{i=2}^n x^{d(w_1, w_i)} + \sum_{i=3}^n x^{d(w_2, w_i)} + \dots + x^{d(w_{n-1}, w_n)} \right] \right. \\
 & + \left[\sum_{i=2}^n x^{d(x_1, x_i)} + \sum_{i=3}^n x^{d(x_2, x_i)} + \dots + x^{d(x_{n-1}, x_n)} \right] + \dots \\
 & \left. + \left[\sum_{i=2}^n x^{d(z_1, z_i)} + \sum_{i=3}^n x^{d(z_2, z_i)} + \dots + x^{d(z_{n-1}, z_n)} \right] \right\} \\
 & + \left\{ \left(\left[\sum_{i=1}^n x^{d(w_1, x_i)} + \sum_{i=1}^n x^{d(w_2, x_i)} + \dots + \sum_{i=1}^n x^{d(w_n, x_i)} \right] \right. \right. \\
 & + \left[\sum_{i=1}^n x^{d(w_1, z_i)} + \sum_{i=1}^n x^{d(w_2, z_i)} + \dots + \sum_{i=1}^n x^{d(w_n, z_i)} \right] \\
 & + \dots + \left[\sum_{i=1}^n x^{d(w_1, z_i)} + \sum_{i=1}^n x^{d(w_2, z_i)} + \dots + \sum_{i=1}^n x^{d(w_n, z_i)} \right] \Big) \\
 & + \left(\left[\sum_{i=1}^n x^{d(x_1, z_i)} + \sum_{i=1}^n x^{d(x_2, z_i)} + \dots + \sum_{i=1}^n x^{d(x_n, z_i)} \right] \right. \\
 & \left. + \dots + \left[\sum_{i=1}^n x^{d(x_1, z_i)} + \sum_{i=1}^n x^{d(x_2, z_i)} + \dots + \sum_{i=1}^n x^{d(x_n, z_i)} \right] \right) + \dots \Big\}
 \end{aligned}$$



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$$= mx + \left(\frac{m^2 - m}{2}\right)x^2 + mnx^2 + mnx + nx^3(m^2 - m) + \left(\frac{n^2 - n}{2}\right)mx^2 + \left(\frac{m^2 - m}{2}\right)n^2x^4$$

$$W(T_m^*; x) = \left(\frac{m^2n^2 - mn^2}{2}\right)x^4 + (m^2n - mn)x^3 + \left(\frac{m^2 + mn^2 - m + mn}{2}\right)x^2 + (mn + m)x$$

Theorem: 3.5

The degree distance index and degree distance polynomial of the graph T_m^* defined in 2.5 is given by

$$DD(T_m^*) = m^2(7n^2 + 10n + 3) - m(4n^2 + 5n + 1)$$

$$DD(T_m^*; x) = mx^{m+n+1} + \left(\frac{m^2 - m}{2}\right)[x^{4n+4} + n^2x^8] + mn(x^{2m+2} + x^{n+2}) + (m^2n - mn)x^{3n+6}$$

$$+ \left(\frac{mn^2 - mn}{2}\right)x^4$$

Proof:

The degree distance index of the graph T_m^* is given by

$$DD(T_m^*) = \sum_{i=1}^m [d(u) + d(v_i)]d(u, v_i)$$

$$+ \left[\sum_{i=2}^m [d(v_1) + d(v_i)]d(v_1, v_i) \right.$$

$$+ \sum_{i=3}^m [d(v_2) + d(v_i)]d(v_2, v_i) + \dots + [d(v_{m-1}) + d(v_m)]d(v_{m-1}, v_m) \left. \right]$$

$$+ \left[\sum_{i=1}^n [d(u) + d(w_i)]d(u, w_i) + \sum_{i=1}^n [d(u) + d(x_i)]d(u, x_i) + \dots + \sum_{i=1}^n [d(u) + d(z_i)]d(u, z_i) \right]$$

$$+ \left\{ \left[\sum_{i=1}^n [d(v_1) + d(w_i)]d(v_1, w_i) + \sum_{i=1}^n [d(v_1) + d(x_i)]d(v_1, x_i) + \dots \right. \right.$$

$$+ \left. \sum_{i=1}^n [d(v_1) + d(z_i)]d(v_1, z_i) \right]$$

$$+ \left[\sum_{i=1}^n [d(v_2) + d(w_i)]d(v_2, w_i) + \sum_{i=1}^n [d(v_2) + d(x_i)]d(v_2, x_i) + \dots \right.$$

$$+ \left. \sum_{i=1}^n [d(v_2) + d(z_i)]d(v_2, z_i) \right] + \dots$$

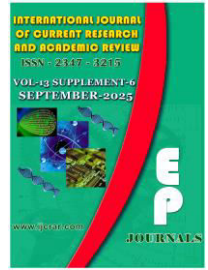


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$$\begin{aligned}
 & + \left[\sum_{i=1}^n [d(v_m) + d(w_i)]d(v_m, w_i) \right. \\
 & + \sum_{i=1}^n [d(v_m) + d(x_i)]d(v_m, x_i) + \dots + \sum_{i=1}^n [d(v_m) + d(z_i)]d(v_m, z_i) \Bigg] \\
 & + \left\{ \left[\sum_{i=2}^n [d(w_1) + d(w_i)]d(w_1, w_i) + \sum_{i=3}^n [d(w_2) + d(w_i)]d(w_2, w_i) + \dots \right. \right. \\
 & \quad \left. \left. + [d(w_{n-1}) + d(w_n)]d(w_{n-1}, w_n) \right] \right. \\
 & + \left[\sum_{i=2}^n [d(x_1) + d(x_i)]d(x_1, x_i) + \sum_{i=3}^n [d(x_2) + d(x_i)]d(x_2, x_i) + \dots \right. \\
 & \quad \left. + [d(x_{n-1}) + d(x_n)]d(x_{n-1}, x_n) \right] + \dots \\
 & + \left[\sum_{i=2}^n [d(z_1) + d(z_i)]d(z_1, z_i) + \sum_{i=3}^n [d(z_2) + d(z_i)]d(z_2, z_i) + \dots + [d(z_{n-1}) + d(z_n)]d(z_{n-1}, z_n) \right] \Bigg\} \\
 & + \left\{ \left(\left[\sum_{i=1}^n [d(w_1) + d(x_i)]d(w_1, x_i) + \sum_{i=1}^n [d(w_2) + d(x_i)]d(w_2, x_i) + \dots \right. \right. \right. \\
 & \quad \left. \left. + \sum_{i=1}^n [d(w_n) + d(x_i)]d(w_n, x_i) \right] \right. \\
 & + \left[\sum_{i=1}^n [d(w_1) + d(y_i)]d(w_1, y_i) + \sum_{i=1}^n [d(w_2) + d(y_i)]d(w_2, y_i) + \dots \right. \\
 & \quad \left. + \sum_{i=1}^n [d(w_n) + d(y_i)]d(w_n, y_i) \right] + \dots \\
 & + \left[\sum_{i=1}^n [d(w_1) + d(z_i)]d(w_1, z_i) + \sum_{i=1}^n [d(w_2) + d(z_i)]d(w_2, z_i) + \dots \right. \\
 & \quad \left. + \sum_{i=1}^n [d(w_n) + d(z_i)]d(w_n, z_i) \right] \Bigg) \Bigg\}
 \end{aligned}$$



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$$\begin{aligned}
 & + \left(\left[\sum_{i=1}^n [d(x_1) + d(y_i)]d(x_1, y_i) + \sum_{i=1}^n [d(x_2) + d(y_i)]d(x_2, y_i) + \dots + \sum_{i=1}^n [d(x_n) + d(y_i)]d(x_n, y_i) \right] \right. \\
 & \quad + \dots \\
 & \quad \left. + \left[\sum_{i=1}^n [d(x_1) + d(z_i)]d(x_1, z_i) + \sum_{i=1}^n [d(x_2) + d(z_i)]d(x_2, z_i) + \dots + \sum_{i=1}^n [d(x_n) + d(z_i)]d(x_n, z_i) \right] \right) \\
 & \quad + \dots \Big\} \\
 & = m(m+n+1) + [(m-1)(4n+4) + (m-2)(4n+4) + \dots + (4n+4)] \\
 & + [n(2m+2) + n(2m+2) + \dots + n(2m+2)]m \text{ times} + [mn(n+2) + (m^2-m)(3n^2+6n)]
 \end{aligned}$$

$$+ [2(n^2-n) + 2(n^2-n) + \dots + 2(n^2-n)]m \text{ times} + [(m-1)8n^2 + (m-2)8n^2 + \dots + 8n^2]$$

$$DD(T_m^*) = m^2(7n^2 + 10n + 3) - m(4n^2 + 5n + 1)$$

The degree distance polynomial of the graph T_m^* is given by

$$\begin{aligned}
 DD(T_m^*; x) &= \sum_{i=1}^m x^{[d(u)+d(v_i)]d(u, v_i)} \\
 &+ \left[\sum_{i=2}^m x^{[d(v_1)+d(v_i)]d(v_1, v_i)} + \sum_{i=3}^m x^{[d(v_2)+d(v_i)]d(v_2, v_i)} + \dots + x^{[d(v_{m-1})+d(v_m)]d(v_{m-1}, v_m)} \right] \\
 &+ \left[\sum_{i=1}^n x^{[d(u)+d(w_i)]d(u, w_i)} + \sum_{i=1}^n x^{[d(u)+d(x_i)]d(u, x_i)} + \dots + \sum_{i=1}^n x^{[d(u)+d(z_i)]d(u, z_i)} \right] \\
 &+ \left\{ \left[\sum_{i=1}^n x^{[d(v_1)+d(w_i)]d(v_1, w_i)} + \sum_{i=1}^n x^{[d(v_1)+d(x_i)]d(v_1, x_i)} + \dots + \sum_{i=1}^n x^{[d(v_1)+d(z_i)]d(v_1, z_i)} \right] \right. \\
 &+ \left[\sum_{i=1}^n x^{[d(v_2)+d(w_i)]d(v_2, w_i)} + \sum_{i=1}^n x^{[d(v_2)+d(x_i)]d(v_2, x_i)} + \dots + \sum_{i=1}^n x^{[d(v_2)+d(z_i)]d(v_2, z_i)} \right] + \dots \\
 &+ \left. \left[\sum_{i=1}^n x^{[d(v_m)+d(w_i)]d(v_m, w_i)} + \sum_{i=1}^n x^{[d(v_m)+d(x_i)]d(v_m, x_i)} + \dots + \sum_{i=1}^n x^{[d(v_m)+d(z_i)]d(v_m, z_i)} \right] \right\} \\
 &+ \left\{ \left[\sum_{i=2}^n x^{[d(w_1)+d(w_i)]d(w_1, w_i)} + \sum_{i=3}^n x^{[d(w_2)+d(w_i)]d(w_2, w_i)} + \dots + x^{[d(w_{n-1})+d(w_n)]d(w_{n-1}, w_n)} \right] \right\}
 \end{aligned}$$

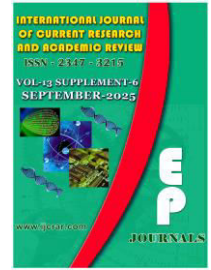


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$$\begin{aligned}
 & + \left[\sum_{i=2}^n \chi^{[d(x_1)+d(x_i)]d(x_1x_i)} + \sum_{i=3}^n \chi^{[d(x_2)+d(x_i)]d(x_2x_i)} + \dots + \chi^{[d(x_{n-1})+d(x_n)]d(x_{n-1}x_n)} \right] + \dots \\
 & + \left[\sum_{i=2}^n \chi^{[d(z_1)+d(z_i)]d(z_1z_i)} + \sum_{i=3}^n \chi^{[d(z_2)+d(z_i)]d(z_2z_i)} + \dots + \chi^{[d(z_{n-1})+d(z_n)]d(z_{n-1}z_n)} \right] \\
 & + \left\{ \left(\sum_{i=1}^n \chi^{[d(w_1)+d(x_i)]d(w_1x_i)} + \sum_{i=1}^n \chi^{[d(w_2)+d(x_i)]d(w_2x_i)} + \dots + \sum_{i=1}^n \chi^{[d(w_n)+d(x_i)]d(w_nx_i)} \right) \right. \\
 & + \left[\sum_{i=1}^n \chi^{[d(w_1)+d(y_i)]d(w_1y_i)} + \sum_{i=1}^n \chi^{[d(w_2)+d(y_i)]d(w_2y_i)} + \dots + \sum_{i=1}^n \chi^{[d(w_n)+d(y_i)]d(w_ny_i)} \right] + \dots \\
 & + \left. \left[\sum_{i=1}^n \chi^{[d(w_1)+d(z_i)]d(w_1z_i)} + \sum_{i=1}^n \chi^{[d(w_2)+d(z_i)]d(w_2z_i)} + \dots + \sum_{i=1}^n \chi^{[d(w_n)+d(z_i)]d(w_nz_i)} \right] \right\} \\
 & + \left(\left[\sum_{i=1}^n \chi^{[d(x_1)+d(y_i)]d(x_1y_i)} + \sum_{i=1}^n \chi^{[d(x_2)+d(y_i)]d(x_2y_i)} + \dots + \sum_{i=1}^n \chi^{[d(x_n)+d(y_i)]d(x_ny_i)} \right] + \dots \right. \\
 & + \left. \left[\sum_{i=1}^n \chi^{[d(x_1)+d(z_i)]d(x_1z_i)} + \sum_{i=1}^n \chi^{[d(x_2)+d(z_i)]d(x_2z_i)} + \dots + \sum_{i=1}^n \chi^{[d(x_n)+d(z_i)]d(x_nz_i)} \right] \right) + \dots \Big\} \\
 DD(T_m^*; x) &= mx^{m+n+1} + [(m-1) + (m-2) + \dots + 1]x^{4n+4} + mn x^{2m+2} + mn x^{n+2} + (m^2 - m)nx^{3n+6} \\
 &+ m \left(\frac{n^2 - n}{2} \right) x^4 + [(m-1) + (m-2) + \dots + 1]n^2 x^8 \\
 DD(T_m^*; x) &= mx^{m+n+1} + \left(\frac{m^2 - m}{2} \right) [x^{4n+4} + n^2 x^8] + mn(x^{2m+2} + x^{n+2}) + (m^2 n - mn)x^{3n+6} \\
 &+ \left(\frac{mn^2 - mn}{2} \right) x^4
 \end{aligned}$$

Definition: 3.6 Octopus Graph [1]

Octopus graph is denoted by O_n .

- O_1 is constructed from cycle C_4 by joining a pendant vertex to one of its vertex.
- O_2 is constructed from O_1 by joining a pendant vertex to a vertex of degree 3.
- O_3 is constructed from O_2 by joining a pendant vertex to a vertex of degree 4.
- O_n is constructed from O_{n-1} by joining a pendant vertex to a vertex of degree $n+1$



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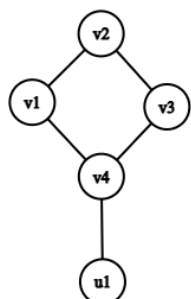


Figure 2: O_1

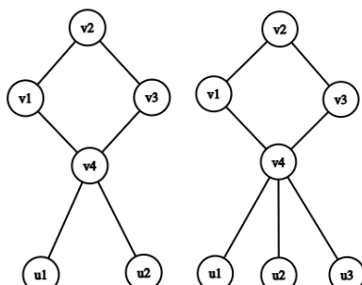


Figure 3: O_2

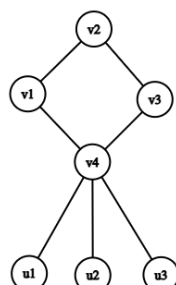


Figure 4: O_3

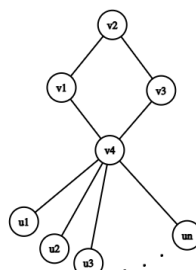


Figure 5: O_n

Theorem: 3.7

The Wiener index and Wiener polynomial of the Octopus graph O_2 is given by $W(O_2) = 26$ and $W(O_2; x) = 2x^3 + 7x^2 + 6x$

Proof:

The Wiener index of the Octopus graph O_2 is given by

$$W(O_2) = \sum_{i=2}^4 d(v_1, v_i) + \sum_{i=3}^4 d(v_2, v_i) + d(v_3, v_4) + \sum_{i=1}^4 d(v_i, u_1) + \sum_{i=1}^4 d(v_i, u_2) + d(u_1, u_2)$$

$$W(O_2) = 1 + 2 + 1 + 1 + 2 + 1 + 2 + 3 + 2 + 1 + 2 + 3 + 2 + 1 + 2 = 26$$

The Wiener polynomial of the Octopus graph O_2 is given by

$$W(O_2; x) = \sum_{i=2}^4 x^{d(v_1, v_i)} + \sum_{i=3}^4 x^{d(v_2, v_i)} + x^{d(v_3, v_4)} + \sum_{i=1}^4 x^{d(v_i, u_1)} + \sum_{i=1}^4 x^{d(v_i, u_2)} + x^{d(u_1, u_2)}$$

$$W(O_2; x) = x + x^2 + x + x + x^2 + x + x^2 + x^3 + x^2 + x + x^2 + x^3 + x^2 + x + x^2$$

$$W(O_2; x) = 2x^3 + 7x^2 + 6x$$

Theorem: 3.8

The degree distance index and degree distance polynomial of the Octopus graph O_2 is given by $DD(O_2) = 96$ and $DD(O_2; x) = x^{12} + 2x^9 + x^8 + 6x^6 + 2x^5 + 3x^4$

Proof:

The degree distance index of the Octopus graph O_2 is given by

$$DD(O_2) = \sum_{i=2}^4 [d(v_1) + d(v_i)]d(v_1, v_i) + \sum_{i=3}^4 [d(v_2) + d(v_i)]d(v_2, v_i) + [d(v_3) + d(v_4)]d(v_3, v_4)$$

$$+ \sum_{i=1}^4 [d(v_i) + d(u_1)]d(v_i, u_1) + \sum_{i=1}^4 [d(v_i) + d(u_2)]d(v_i, u_2) + [d(u_1) + d(u_2)]d(u_1, u_2)$$

$$DD(O_2) = 4 + 8 + 6 + 4 + 12 + 6 + 6 + 9 + 6 + 5 + 6 + 9 + 6 + 5 + 4 = 96$$

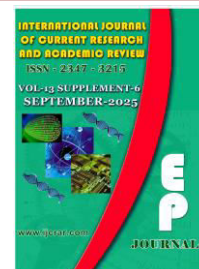


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The degree distance polynomial of the Octopus graph O_2 is given by

$$DD(O_2; x) = \sum_{i=2}^4 x^{[d(v_1)+d(v_i)]d(v_1,v_i)} + \sum_{i=3}^4 x^{[d(v_2)+d(v_i)]d(v_2,v_i)} + x^{[d(v_3)+d(v_4)]d(v_3,v_4)} \\ + \sum_{i=1}^4 x^{[d(v_i)+d(u_1)]d(v_i,u_1)} + \sum_{i=1}^4 x^{[d(v_i)+d(u_2)]d(v_i,u_2)} + x^{[d(u_1)+d(u_2)]d(u_1,u_2)} \\ DD(O_2; x) = x^4 + x^8 + x^6 + x^4 + x^{12} + x^6 + x^6 + x^9 + x^6 + x^5 + x^6 + x^9 + x^6 + x^5 + x^4 \\ DD(O_2; x) = x^{12} + 2x^9 + x^8 + 6x^6 + 2x^5 + 3x^4$$

Theorem: 3.9

The Wiener index and Wiener polynomial of the Octopus graph O_n is given by

$$W(O_n) = n^2 + 7n + 8 \text{ and } W(O_n; x) = nx^3 + \left(\frac{n^2+3n+4}{2}\right)x^2 + (n+4)x$$

Proof:

The Wiener index of the Octopus graph O_n is given by

$$W(O_n) = \sum_{i=2}^4 d(v_1, v_i) + \sum_{i=3}^4 d(v_2, v_i) + d(v_3, v_4) + \sum_{i=1}^n d(v_1, u_i) + \sum_{i=1}^n d(v_2, u_i) + \sum_{i=1}^n d(v_3, u_i) \\ + \sum_{i=1}^n d(v_4, u_i) + \sum_{i=2}^n d(u_1, u_i) + \sum_{i=3}^n d(u_2, u_i) + \dots + d(u_{n-1}, u_n) \\ W(O_n) = 8 + 2n + 3n + 2n + n + [(n-1)2 + (n-2)2 + \dots + 2] \\ W(O_n) = n^2 + 7n + 8$$

The Wiener polynomial of the Octopus graph O_n is given by

$$W(O_n; x) = \sum_{i=2}^4 x^{d(v_1,v_i)} + \sum_{i=3}^4 x^{d(v_2,v_i)} + x^{d(v_3,v_4)} + \sum_{i=1}^n x^{d(v_1,u_i)} + \sum_{i=1}^n x^{d(v_2,u_i)} + \sum_{i=1}^n x^{d(v_3,u_i)} \\ W(O_n; x) = x + x^2 + x + x + x^2 + x + nx^2 + nx^3 + nx^2 + nx + [(n-1) + (n-2) + \dots + 1]x^2 \\ W(O_n; x) = nx^3 + \left(\frac{n^2+3n+4}{2}\right)x^2 + (n+4)x$$

Theorem: 3.10

The degree distance index and degree distance polynomial of the Octopus graph O_n is given by

$$DD(O_n) = 3n^2 + 26n + 32 \text{ and } DD(O_n; x) = x^{2n+8} + 2x^{n+4} + nx^{n+3} + nx^9 + x^8 + 2nx^6 + \left(\frac{n^2-n+4}{2}\right)x^4$$

Proof:

The degree distance index of the Octopus graph O_n is given by

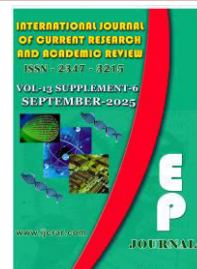


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$$\begin{aligned}
 DD(O_n) &= \sum_{i=2}^4 [d(v_1) + d(v_i)]d(v_1, v_i) + \sum_{i=3}^4 [d(v_2) + d(v_i)]d(v_2, v_i) + [d(v_3) + d(v_4)]d(v_3, v_4) \\
 &+ \sum_{i=1}^n [d(v_1) + d(u_i)]d(v_1, u_i) + \sum_{i=1}^n [d(v_2) + d(u_i)]d(v_2, u_i) + \sum_{i=1}^n [d(v_3) + d(u_i)]d(v_3, u_i) \\
 &+ \sum_{i=1}^n [d(v_4) + d(u_i)]d(v_4, u_i) + \sum_{i=2}^n [d(u_1) + d(u_i)]d(u_1, u_i) + \sum_{i=3}^n [d(u_2) + d(u_i)]d(u_2, u_i) \\
 &+ \dots + [d(u_{n-1}) + d(u_n)]d(u_{n-1}, u_n) \\
 DD(O_n) &= 4 + 8 + (n + 4) + 4 + (2n + 8) + (n + 4) + 6n + 9n + 6n + n(n + 3) \\
 &+ [(n - 1)4 + (n - 2)4 + \dots + 4] \\
 DD(O_n) &= 3n^2 + 26n + 32
 \end{aligned}$$

The degree distance Polynomial of the Octopus graph O_n is given by

$$\begin{aligned}
 DD(O_n; x) &= \sum_{i=2}^4 x^{[d(v_1)+d(v_i)]d(v_1, v_i)} + \sum_{i=3}^4 x^{[d(v_2)+d(v_i)]d(v_2, v_i)} + x^{[d(v_3)+d(v_4)]d(v_3, v_4)} \\
 &+ \sum_{i=1}^n x^{[d(v_1)+d(u_i)]d(v_1, u_i)} + \sum_{i=1}^n x^{[d(v_2)+d(u_i)]d(v_2, u_i)} + \sum_{i=1}^n x^{[d(v_3)+d(u_i)]d(v_3, u_i)} \\
 &+ \sum_{i=1}^n x^{[d(v_4)+d(u_i)]d(v_4, u_i)} + \sum_{i=2}^n x^{[d(u_1)+d(u_i)]d(u_1, u_i)} + \sum_{i=3}^n x^{[d(u_2)+d(u_i)]d(u_2, u_i)} \\
 &+ \dots + x^{[d(u_{n-1})+d(u_n)]d(u_{n-1}, u_n)} \\
 DD(O_n; x) &= x^4 + x^8 + x^{n+4} + x^4 + x^{2n+8} + x^{n+4} + nx^6 + nx^9 + nx^6 + nx^{n+3} \\
 &+ [(n - 1)x^4 + (n - 2)x^4 + \dots + x^4] \\
 DD(O_n; x) &= x^{2n+8} + 2x^{n+4} + nx^{n+3} + nx^9 + x^8 + 2nx^6 + \left(\frac{n^2 - n + 4}{2}\right)x^4
 \end{aligned}$$

Conclusion

For a small number of graph families, topological indices and topological polynomials have been discovered, and properties have been used to cross-check the validity of the stated theorems. Our investigation will proceed by taking into account chemical substances like

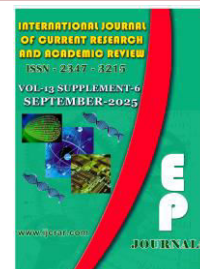


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pentacene and perylene, as well as their underlying chemical graphs, determining their topological indices, and applying them in various applications.

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Full Length Article

IJCRAR/FL/80

Optimization of Transportation Problems Using Various Methods with Real-Life Application

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Abstract

Transportation problems play a significant role in supply chain and logistics management, where the goal is to minimize the cost of transporting goods from multiple sources to multiple destinations. In real-life scenarios, organizations such as Amazon, Flipkart, and DHL optimize transportation routes to reduce operational costs and delivery times. This paper explores four widely used methods for solving transportation problems: North-West Corner Rule (NWCR), Least Cost Method (LCM), Row/Column Minima Method (RMM/CMM), and Vogel's Approximation Method (VAM). A comparative analysis is conducted using a common example problem to demonstrate differences in allocation strategies and total costs. A graphical representation of the results is provided and real-life applications are discussed to highlight the significance of these optimization techniques.

Keywords: Transportation Problem, Optimization, NWCR, LCM, RMM, VAM, Operations Research, Cost Minimization.

Introduction

The transportation problem is a special type of linear programming problem in operations research that focuses on finding the most efficient way to distribute products from multiple suppliers (sources) to multiple consumers (destinations) while minimizing the total transportation cost.

Transportation problems have a wide range of applications in industries such as:

- ✓ E-commerce

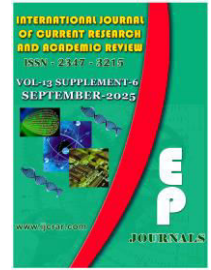


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- ✓ Food delivery
- ✓ Manufacturing and raw material distribution
- ✓ Hospitals and medical supply chains
- ✓ Fuel and energy distribution

In this paper, we demonstrate four different methods used to solve transportation problems, compare their results, and analyze their applicability in real-world situations.

Literature review:

- ✓ Transportation problems have been widely studied in operations research due to their importance in optimizing supply chain costs.
- ✓ Adlakha & Kowalski (2009) compared NWCR, LCM, and VAM and concluded that VAM provides better initial solutions than other methods.
- ✓ Kirca & Satir (1990) analyzed heuristic approaches and found that LCM performs better than NWCR, while VAM produces solutions closest to the optimal cost.
- ✓ Rehman & Khan (2017) evaluated different transportation problem-solving techniques and showed that RMM and VAM are more efficient for minimizing costs in larger problems.
- ✓ Chakraborty & Dutta (2020) highlighted the real-life applications of these optimization methods, showing how companies like Amazon, Flipkart, and DHL use them to reduce operational expenses and improve delivery efficiency.
- ✓ These studies collectively indicate that although all four methods are useful, VAM is generally the most effective when minimizing transportation costs.

Example problem:

Consider the following transportation problem with 3 factories (F1, F2, F3) and 3 warehouses (W1, W2, W3):

FACTORY	W1	W2	W3	SUPPLY
F1	4	8	8	20
F2	8	4	6	30
F3	6	8	4	25
DEMAND	25	25	25	



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North West corner rule(NWCR):

1. Start from the top-left (north-west) cell.
2. Allocate as much as possible without exceeding supply/ demand.
3. Move right if demand is met, or down if supply is exhausted.

Result:

Total Transportation Cost = ₹660

Least Cost Method (LCM)

Steps:

1. Find the cell with the lowest transportation cost.
2. Allocate as much as possible.
3. Cross out satisfied row/column and repeat.

Result:

Total Transportation Cost = ₹600

Row/Column Minima Method (RMM/CMM)

Steps:

1. Choose the minimum cost in each row or column.
2. Allocate accordingly until supply/ demand is satisfied.

Result:

Total Transportation Cost = ₹590

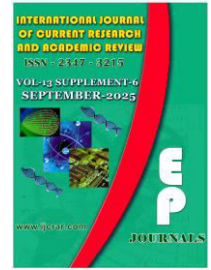


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Vogel's Approximation Method (VAM)

Steps:

1. Calculate penalties for each row and column based on the difference between the smallest and second-smallest costs.
2. Allocate to the cell with the highest penalty first.
3. Repeat until all supplies and demands are met.

Result:

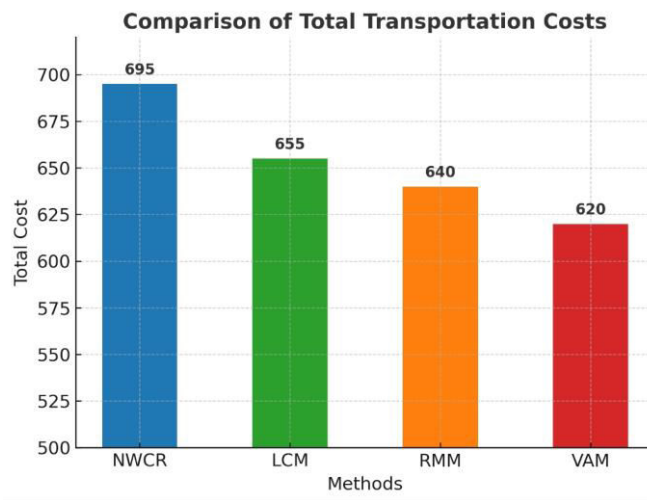
Total Transportation Cost = ₹580

Comparison table:

METHOD	TOTAL COST (₹)
NWCR	660
LCM	600
RMM/CMM	590
VAM	580

Graphical Comparison:

(This bar chart compares total costs among the four methods.)





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Real-life applications:

E-commerce: Amazon, Flipkart use optimization for fast, low-cost deliveries.

Food Delivery: Zomato & Swiggy assign orders optimally to riders.

Healthcare: Hospitals manage distribution of medicines and equipment.

Manufacturing: Efficient movement of raw materials reduces costs.

Energy & Fuel: Oil companies minimize transportation expenses.

Conclusion

Optimizing transportation problems helps minimize operational costs and improve efficiency. Among the four methods, VAM consistently yields the lowest transportation cost, making it a preferred approach in most real-world cases. However, the choice of method depends on problem size, cost structure, and organizational goals.

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Full Length Article

IJCRAR/FL/81

Fibonacci Numbers and the Golden Ratio: Patterns in Nature and Beyond

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Abstract

Fibonacci numbers and the golden ratio are celebrated for their recurring patterns in both natural and engineered systems. This paper explores novel cyclic properties of Fibonacci sequences in alternative number bases and presents recent biological findings confirming the golden ratio's subtle yet persistent role in growth and structure. The research highlights mathematical foundations, ecological applications, modeling methods, and challenges. The paper also provides visual examples, discusses future prospects, and illustrates how these ancient numbers and ratios remain central to modern research across disciplines.

Keywords: Fibonacci Sequence, Golden Ratio, Mathematical Patterns, Nature, Modeling, Base-12 Analysis, Biological Systems

Introduction

The study of Fibonacci numbers and the golden ratio reveals mathematical structures woven into the fabric of nature itself. From spiral arrangements in plants to proportions in human-made architecture, their recurring appearances inspire exploration and discovery. Recent investigations have uncovered new cyclic patterns in Fibonacci sequences under non-standard bases, and have provided stronger quantitative evidence for the golden ratio's ecological and aesthetic prevalence. This paper aims to connect mathematical theory to real-world patterns, offering fresh insights and clear illustrations for interdisciplinary research.

The core mathematical concepts and results presented in this paper are based on established sources by Knott (1), Weisstein (2), and the collaborative Wikipedia community (3),

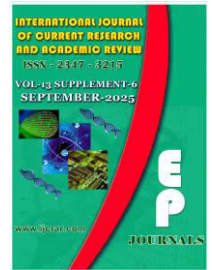


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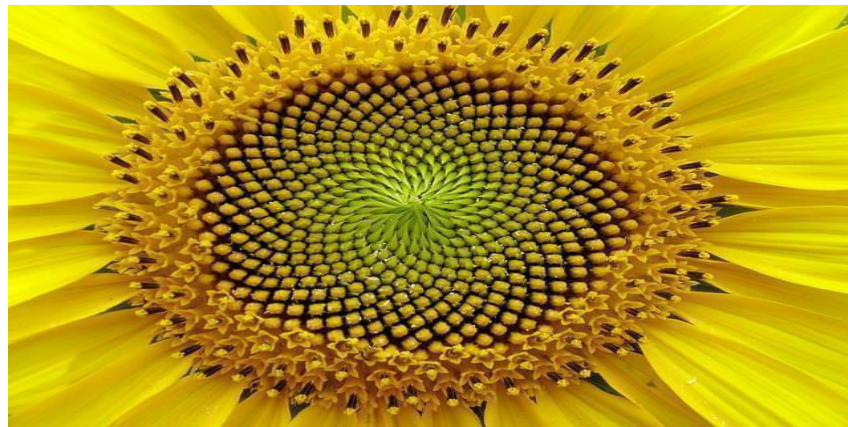
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which provide comprehensive insights into Fibonacci numbers, their properties, and related identities.



Mathematical Foundations

Fibonacci Sequence: Defined recursively as $F_n = F_{n-1} + F_{n-2}$, with $F_0 = 0$, $F_1 = 1$.

Golden Ratio (ϕ): Long-term limit $F_{n+1} / F_n \rightarrow \phi = (1 + \sqrt{5})/2 \approx 1.618$.

Unique Discoveries

Base-12 Patterns: Analysis has revealed repeating cycles in the Fibonacci sequence when expressed in base-12, with a distinct periodicity every 24 terms—a new phenomenon not observed in the decimal system.

Ecological Findings: Studies confirm the golden ratio appears in arrangement of leaves (phyllotaxis), animal anatomy, and even human visual preference, with quantifiable data from biology and psychology.

Geometric Models: Mapping Fibonacci and golden ratio spirals in new mathematical frames reveals symmetries useful for modeling natural growth and formation.



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Importance of Mathematical Modelling

Mathematical modelling helps us understand and predict complex systems, particularly where Fibonacci numbers and the golden ratio appear. The importance includes:
Understanding Systems: Clarifies how natural structures like plants and shells grow following these patterns.

Prediction: Forecasts growth trends or structural development in ecological and biological contexts.

Optimization: Helps identify efficient packing or arrangement strategies in nature, such as seed placement in sunflowers.

Decision-Making: Supports decisions in agriculture, environmental management, and design based on modeled growth patterns.

Innovation: Inspires architectural and artistic designs based on natural geometric proportions.

Communication: Offers a common language bridging biology, mathematics, and engineering.

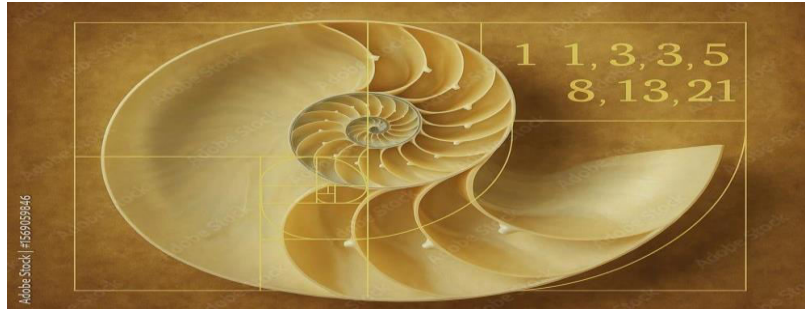


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Types of Models Relevant to Fibonacci and Golden Ratio Studies

The mathematical phenomena related to Fibonacci numbers and the golden ratio can be studied using various models:

Deterministic Models: Equations defining exact Fibonacci sequences and golden ratio calculations without randomness.

Stochastic Models: Used when biological growth involves probabilistic elements and environmental variability.

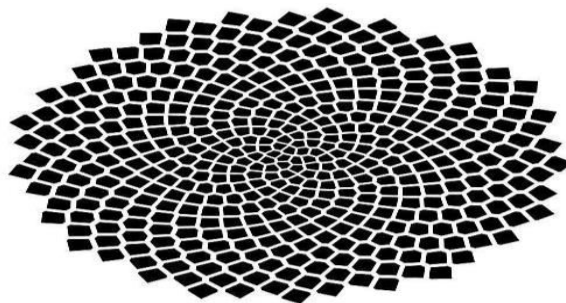
Continuous Models: Describe growth or changes over a continuous scale, such as leaf arrangement angles in phyllotaxis.

Discrete Models: Model discrete steps, matching the integer nature of Fibonacci numbers.

Nonlinear Models: Capture complex growth dynamics that simple linear models cannot explain, such as chaotic branching patterns.

Dynamic Models: Study how these patterns emerge and evolve over time in plants and organisms.

Machine Learning Models: Can identify Fibonacci-like patterns in large datasets from nature or art using algorithms.





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Applied Mathematical Problems Demonstrating My Discoveries

Problem 1: Fibonacci Numbers in Base-12 and Cyclicity

Calculate the first 30 Fibonacci numbers and convert each into base-12.

n	Fibonacci (decimal)	Fibonacci (base-12)	Last two digits (base-12)
1	1	1	01
2	1	1	01
3	2	2	02
4	3	3	03
24	46368	27430	30
25	75025	43919	19

Show that the last two digits in base-12 repeat every 24 terms, demonstrating a cyclic pattern unique to the duodecimal system.

Problem 2: Convergence to Golden Ratio with Values

Calculate ratios $F(n+1)/F(n)$ for $n=1$ to 15:

n	F(n)	F(n+1)	Ratio $F(n+1)/F(n)$
1	1	1	1
2	1	2	2
3	2	3	1.5
4	3	5	1.6667
5	5	8	1.6
15	610	987	1.61803

Plot these values and show progressively closer approximations to $\phi = 1.61803$, reinforcing its fundamental nature in growth and geometry.



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Problem 3: Leaf Divergence Angles in Degrees

Using the golden angle about 137.5° , calculate the angular positions for leaves number 10, 15, and 20 around a stem (mod 360°):

$$\theta(n) = (n \times 137.5) \bmod 360$$

Leaf number (n)	$\theta(n)$
10	15°
15	262.5°
20	230°

This demonstrates how leaf positions avoid overlap, maximizing light exposure, which reflects natural optimization.

Problem 4: Sum of Fibonacci Numbers and Modulo 12

Prove and verify for $n=12$:

$$\sum_{k=0}^n F(k) = F(n+2) - 1$$

Calculate numerically:

- Sum F_0 to F_{12} in decimal.
- Compute $F_{14} - 1$.
- Find both modulo 12 and verify they are congruent.

Applications

Biology: Modeling population growth, leaf arrangement, and reproductive strategies.

Art & Architecture: Proportioning spaces and artworks for optimal harmony and balance.

Engineering: Sequence-based algorithms for optimization and digital signal processing.

Finance: Detecting cycles and patterns in stock market analysis.

Computational Science: Enhancing AI algorithms through mathematical insights.

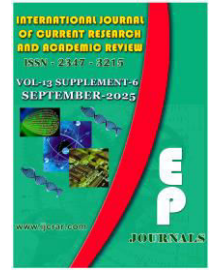


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Challenges

Complexity: Real-world phenomena often deviate from ideal mathematical regularity.

Assumptions: Over-simplification can mislead interpretation of observed patterns.

Computational Limits: Modern analysis, especially in larger datasets or alternative bases, requires advanced computational power.

Communication: Explaining mathematical significance to general audiences is often difficult.

Future Prospects

Artificial Intelligence: Integrating sequence and ratio properties for improved pattern recognition.

Interdisciplinary Collaboration: Further blending mathematics, biology, and the arts.

Big Data: Applying advanced analytics to uncover hidden Fibonacci/golden ratio patterns in massive ecological or economic datasets.

Visualization: Creating interactive models for educational and research use.

Real-Time Modelling: Building dynamic models to understand complex systems as they evolve.

Conclusion

Fibonacci numbers and the golden ratio continue to bridge the gap between abstract mathematics and the observable world. Newly discovered properties – such as cyclicity in non-



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decimal bases—expand mathematical knowledge and offer practical modeling tools for science and design. With advances in computation and interdisciplinary research, these patterns will inform future breakthroughs in understanding natural order, aesthetics, and systems architecture.

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Full Length Article

IJCRAR/FL/82

Operation Research Management

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Abstract

Operations Research (OR) provides a scientific basis for solving complex decision-making problems by applying mathematical modeling and optimization techniques. Among its core tools are the assignment problem, transportation problem, sequencing problem, and game theory, each addressing distinct yet complementary aspects of operational efficiency and strategic decision-making. The assignment problem ensures optimal one-to-one allocation of resources to tasks, while the transportation problem minimizes distribution costs in supply chains. Sequencing problems focus on determining the most efficient order of executing jobs on machines to minimize makespan and idle time. In contrast, game theory models competitive or adversarial decision-making situations, helping organizations develop robust strategies under uncertainty. This paper examines the mathematical formulations, solution techniques, and applications of these models, highlights their similarities and differences, and discusses their integration in practical contexts. The study emphasizes how these OR models continue to enhance productivity, reduce costs, and provide competitive advantages across diverse industries, from manufacturing and logistics to defense and business strategy.

Keywords: Digital infrastructures, Software Defined Networking (SDN) and Network

Introduction

Decision-making in modern organizations is increasingly complex due to resource limitations, competition, and uncertainty. Traditional intuition-based methods are often insufficient, which has led to the rise of Operations Research (OR) as a systematic and scientific approach. OR applies mathematical models, statistics, and optimization algorithms to assist managers and policymakers in arriving at rational decisions.



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Among the wide range of OR models, four categories play a particularly crucial role:

1. Assignment Problems – focused on optimally allocating resources such as workers, machines, or tasks in a one-to-one fashion.
2. Sequencing Problems – addressing the challenge of finding the optimal order in which jobs should be processed across machines to minimize total elapsed time.
3. Game Theory – providing tools for strategic decision-making when outcomes depend on both one's choices and those of competing players.

These models not only optimize internal processes but also support decision-making in competitive environments. For example:

Airlines use assignment models for crew scheduling, transportation models for cargo distribution, sequencing models for flight/maintenance scheduling, and game theory to anticipate competitor behavior.

Manufacturing industries apply these models for cost reduction, productivity improvement, and competitive advantage.

This paper provides a comprehensive study of assignment problems, transportation problems, sequencing problems, and game theory. Each section discusses the mathematical formulation, solution methods, and practical applications. A comparative analysis highlights the similarities and differences among them, followed by a discussion on their integration in real-world problem-solving. The paper concludes with insights on the importance of these models for modern decision-making and their future potential when combined with artificial intelligence (AI) and big data analytics..

Assignment Problems

The Assignment Problem (AP) is one of the fundamental models in Operations Research (OR). It seeks to optimally allocate a set of resources, agents, or machines to an equal number of tasks, jobs, or activities. The objective is to minimize total cost or time of performing the assignments (or to maximize efficiency or profit). It is essentially a special case of the Transportation Problem, where supply and demand at each source and destination are fixed to one unit.



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Mathematical Formulation

Let there be n jobs and n workers. The cost of assigning worker i to job j is represented by C_{ij} . The decision variable Z_{ij} takes the value 1 if worker i is assigned to job j , and 0 otherwise.

The problem is formulated as:

Minimize $Z = \sum_{i=1}^n \sum_{j=1}^n c_{ij} x_{ij}$

Subject to:

$\sum_{j=1}^n x_{ij} = 1 \quad \forall i$ (each worker get one job)

$x_{ij} \in \{0,1\}$

This ensures that every worker is assigned to exactly one job and each job is performed by exactly one worker.

Solution Technique: The Hungarian Method

The Hungarian Algorithm, developed by Kuhn in (1955), is the most widely used method for solving assignment problems. The steps include:

1. Row reduction: Subtract the smallest value in each row from all entries in that row.
2. Column reduction: Subtract the smallest value in each column from all entries in that column.
3. Covering zeros: Cover all zeros in the reduced matrix using the minimum number of horizontal and vertical lines.

Optimality check:

- If the number of lines = n , an optimal assignment is possible.
- If not, adjust the matrix by subtracting the smallest uncovered element and repeat.

Example

Consider a company with four workers (W_1, W_2, W_3, W_4) and four jobs (J_1, J_2, J_3, J_4). The cost matrix (in hours) is provided.



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	J1	J2	J3	J4
W1	9	2	7	8
W2	6	4	3	7
W3	5	8	1	8
W4	7	6	9	4

By applying the Hungarian Method, the optimal assignment is:

- W1 → J2
- W2 → J3
- W3 → J1
- W4 → J4

The total minimum cost is 13 hours.

Applications

Assignment problems are widely applied in real-life contexts such as:

- Allocating employees to tasks in manufacturing and service industries.
- Assigning salespeople to territories.
- Crew scheduling in airlines, railways, and hospitals.
- Matching students to projects or examiners.

Limitations and Extensions

While the classical assignment problem assumes equal numbers of jobs and workers, real-world scenarios often involve unbalanced cases. These can be solved by introducing dummy rows or columns with zero costs. Extensions also include Multi-objective assignment problems, Probabilistic assignment models and Time-dependent variants

Sequencing Problems

The Sequencing Problem in Operations Research deals with determining the optimal order in which a set of jobs should be processed on one or more machines to minimize a



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performance measure such as total elapsed time, idle time of machines, or makespan. These problems are particularly important in manufacturing and production systems where multiple jobs must pass through several machines.

Case 1: Jobs on 2 Machines

This is the classical Johnson's Rule problem. Each of the jobs must be processed first on Machine A and then on Machine B (or vice versa). The processing times of jobs on both machines are given, and the objective is to minimize the total elapsed time.

Johnson's Rule Procedure:

1. List all jobs with their processing times on both machines.
2. Select the smallest processing time:
 - If it belongs to Machine A, schedule the job as early as possible.
 - If it belongs to Machine B, schedule the job as late as possible.

Repeat until all jobs are sequenced.

This rule provides an optimal sequence with minimum makespan for two-machine flow shop problems.

Case 2: Jobs on 3 Machines

When jobs must pass through three machines in the same order, Johnson's rule can still be applied with modification. If the processing times on the first and third machines dominate those on the second (i.e, $\min(A_i, C_i) \geq B_i$), the three-machine problem can be reduced to a two-machine equivalent:

- Define a fictitious Machine G with processing time $G_i = A_i + B_i$.
- Define a fictitious Machine H with processing time $H_i = B_i + C_i$.

The reduced problem can then be solved using Johnson's rule for two machines.

Case 3: 2 Jobs on m Machines

If only two jobs are to be processed on machines in a fixed order, the sequencing is trivial: each job must follow the machine order. The key decision is whether Job 1 should start before Job 2 or vice versa. The total elapsed time is calculated for both sequences, and the better one is chosen.



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This case is useful in situations such as testing two projects through multiple evaluation stages

Case 4: n Jobs on m Machines

This is the most general form of the sequencing problem. When $n > 2$, and $m > 2$, no simple optimal rule like Johnson's exists. Instead, the problem is formulated as a flow shop scheduling problem, often requiring advanced algorithms such as:

- Branch and Bound methods.
- Heuristics and metaheuristics (e.g., Genetic Algorithms, Tabu Search, Simulated Annealing).
- Approximation methods for minimizing makespan or total completion time
- Due to the computational complexity, the -job -machine sequencing problem is classified as NP-hard $m \geq 3$.

Applications of Sequencing Problems

- Job scheduling in manufacturing plants.
- Assembly line balancing in automotive industries.
- Scheduling of computer tasks in multi-core processors.
- Processing of projects through multiple review stages

Game Theory

Game Theory is a branch of Operations Research and applied mathematics that studies decision-making in situations of conflict and cooperation. It provides a framework to model strategic interactions among rational decision-makers, called players. Each player aims to maximize their own payoff (profit, utility, or benefit), given the possible strategies of other players. Game theory has wide applications in economics, politics, business, and military science.

Classification of Games

1. Two-person zero-sum games: The simplest and most widely studied, where one player's gain equals the other player's loss. For example, in competitive bidding, if one firm gains market share, the other loses it.



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2. Non-zero-sum games: Both players can either gain or lose simultaneously, depending on their strategies.
3. Cooperative vs. Non-cooperative games: In cooperative games, players can form coalitions and share payoffs, while in non-cooperative games each player acts independently.

Pure vs. Mixed strategy games:

- Pure strategy: A player consistently follows one strategy.
- Mixed strategy: A player randomizes choices with certain probabilities to avoid predictability.

Mathematical Formulation of Two-person Zero-sum Games

Suppose two players, Player A (row player) and Player B (column player), have a finite set of strategies. The outcomes are represented in a payoff matrix where a_{ij} denotes the payoff to Player A when A chooses strategy i and B chooses strategy j .

The value of the game (V) can be defined as:

$$V = \max_i \min_j a_{ij} = \min_j \max_i a_{ij}$$

- If these two values are equal, the game has a saddle point, meaning both players have optimal pure strategies.
- If not, the players resort to mixed strategies, selecting strategies with certain probabilities to minimize expected losses (for Player B) or maximize expected gains (for Player A).

Example: Two-person Zero-sum Game

Consider the following payoff matrix (payoffs to Player A):

	B1	B2
A1	2	-1
A2	-3	4

Row minima = -1, -3 so max min = -1.

Column maxima = 2, 4 so mini max = 2.



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Since, $\max \min \neq \min \max$, there is no saddle point. The players must adopt mixed strategies. Using linear programming or probability analysis, equilibrium probabilities can be determined to compute the expected value of the game.

Applications of Game Theory

- Economics & Business: Competitive pricing, market entry strategies, auctions, and bargaining.
- Military & Defense: Strategic planning in conflict situations, such as attack–defense games.
- Political Science: Voting strategies, coalition formation, and international negotiations.
- Computer Science: Cybersecurity, algorithmic game theory, and AI decision-making.

Conclusion

This paper analyzed assignment problems, transportation problems, sequencing problems, and game theory as essential tools of Operations Research.

- Assignment and transportation problems optimize allocation and distribution.
- Sequencing problems optimize execution order and efficiency.
- Game theory models conflict and competition, supporting strategic decisions.

Together, these models provide organizations with cost savings, efficiency gains, and competitive advantage. Future research may focus on integrating them with artificial intelligence (AI), machine learning, and big data analytics for solving dynamic, large-scale, and uncertain problems.

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Full Length Article

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"A BFS-DFS Approach" Semi-Stock-Temporal Graph Traversals for Market Influence

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Abstract

In this study each stock is particularized vertex in Temporal Graph model, and directional co-movements based create an edge on trading days $G_t=(V, [E]_t)$. The discrete time layers are fluctuating the market structure, in imbalance to static graph. Based on Breadth-First Search (BFS) and Depth First Search (DFS), To create a temporal traversal framework to investigate this dynamic market network. Whereas temporal DFS discovers vertical sequence of effect across consecutive days, temporal BFS discovers vertical sequence of effect across Consecutive days, temporal BFS grows level by level across time, capturing the horizontal dispersion of links between equities on each trading day. The Semi-Temporal graph's reachability patterns, linked temporal components, and leading- lagging chains of vertices are all visible through these traversals. This graph-theoretic viewpoint lays the groundwork for developing multigraph structures, constructing temporal routes, and incorporating classical methods into financial network research without depending on statistical models.

Keywords: Semi Temporal Graph (STG), Temporal BFS tree, Temporal DFS path, Temporal Traversal (TT), Temporal Connectivity (TC), Equity Network, Leading- Lagging Sequence, Graph Clustering

Introduction

The use of graph theory to financial markets dates back to Rosario N. Mantegna's (1998) pioneering work, which established the use of a Minimum Spanning Tree (MST) to describe the hierarchical structure of stock correlations. In his model, each stock was represented by a vertex,



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and the correlation between pairs of stock was converted into a weighted edge, from which a spanning tree was built. This graph-theoretical depiction opened up new perspectives on stock clustering and market sectoral structure. However, Mantegna's approach was basically static, providing merely a snapshot the temporal evolution of market dynamics.

Building on this foundation, this study proposes a temporal graph method to stock market analysis. Unlike static MST, our approach includes time into the spanning tree structure. By using Breadth-First search (BFS) and Depth-First search (DFS) traversals across temporal layers of the market graph, we can see how influence spreads between stocks over time. BFS exposes quick, short-term impacts that spread extensively over the market, whereas DFS reveals deeper, sequential relationships that grow over longer time periods.

This combination of temporal spanning trees with BFS/DFS traversal differs from previous static techniques and gives a more comprehensive insight of financial market dynamics. It allows for the detection of lead-lag interactions, the finding of time-varying market clusters, and the simulation of dynamic stock hierarchies. Such a framework is not only theoretically noteworthy, but also practical in terms of portfolio management, risk monitoring, and predictive modelling in current financial systems.

To summarize, our study bridges the gap between graph theory and financial market analysis by expanding the static MST notion to a dynamic temporal model. By incorporating BFS and DFS algorithms into the temporal spanning tree, we develop a unique technique that represents the changing nature of market interactions while also providing fresh insights into the temporal structure of stock market network.

Literature Review

Introduces grouping of stock returns over time, utilizing a graph visualization to show how clusters grow, which aids portfolio methods.[1]

Models the stock market as a temporal network, leveraging temporal centrality to enhance portfolio selection.[2]

Stock market prediction of graph-based approaches in survey application[3]



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Cross-border relationship of forecasting modelling in inter-intra graph neural networks for stock price novel.[4]

STP method on Directed graph for stock trading Network in Simple paths and Cycles.[5]

Analysis of Equity Markets of a graph theory approach.[6], [7]

Preliminaries:

Definition:2.1 Given at temporal graph $G = (\tilde{v}, \epsilon)$ and a starting time t_s , a DFS in G starting time at $\mathbb{T}_s$, named as DFS- $\tilde{u}1$, is defined as follows:

1. Initialize $\sigma(s) = \infty$ for all $v \in \tilde{v}$, and select a source vertex s .
2. Visit s and $\sigma(s) = \mathbb{T}_s$ and go to step 2(b)
 - a) **After visiting vertex u :** Let E_u be the set of temporal edges outgoing from u , where each edge $(u, v, \mathbb{T}) \in \epsilon_u$, has not been traversed before and $\sigma(u) \leq t$.

If $\epsilon_u \neq \emptyset$, we choose the edge $e = (u, v, \mathbb{T}) \in \epsilon_u$, where $t = \max \{\mathbb{T}' : (u, v', \mathbb{T}') \in \epsilon_u\}$, and traverse e and go to step 2(b).

Else (i.e., $\epsilon_u \neq \emptyset$), we backtrack to u 's predecessor u' (i.e., we have just visied u via the temporal edge (u', u, t')) and repeat step 2(a); or if u is the source vertex, then terminate the DFS.

b) After traversing a temporal edge $(u, v, \mathbb{T})$: If $\sigma(v) > \mathbb{T}$, we visit v and set $\sigma(v) = \mathbb{T}$, And go to step 2(a). Else, repeat v and set $\sigma(v) = \mathbb{T}$, and go to Step 2(a). Else, repeat step 2(a).[8]

Definition:2.2 (Time constraint on n-day traversal). Let $G = (V, E_T)$ here temporal graph is called as a n-day trading day and form of the edge (stock A, stockB, time $\mathbb{T}$, w).

A sequence of temporal traversal is a sequence of an intraday edge:

$$\pi = [(s_1, s_2, \mathbb{T}_1, w_1), ((s_1, s_2, \mathbb{T}_2, w_2)), \dots, ((s_1, s_2, \mathbb{T}_k, w_k))]$$

1. Stock Connectivity: Each stock edge end where the next stock edge is started.
2. Ordering of time: The n day order is considering 1-n in-between time is traversal $\mathbb{T}_1, \mathbb{T}_2 \dots \mathbb{T}_k$. Trading sequence day.



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3. Relation retaining: each edge carries a weight is considered predecessor, successor, neutral

If the time condition is a strict temporal path, then it's ($\mathbb{T}_{i+1} > \mathbb{T}_i$),

If small overlaps are allowed ($\mathbb{T}_{i+1} \geq \mathbb{T}_i - \delta$), it becomes a semi-stock-temporal traversal.

Methodology

1. Data Collection

Gather daily closing prices for certain stocks from a CSV file dataset.

Eg: 100 data points (10 stocks and 20 days).

2. Data Processing

Put stock prices in an organized manner. Determine everyday transitions with:

$$\Delta P = P_t - P_{t-1}$$

If $\Delta P > 0 \rightarrow state = '+'$

If $\Delta P < 0 \rightarrow state = '-'$

If $\Delta P = 0 \rightarrow state = '0'$

3. Graph construction

Use Network-X comparable packages to create a semi-temporal graph. The closing price of a stock on a given day is represented by each node. Days are connected by directed edges.

4. Graph Traversal

Compare stock patterns on the same day using the Breadth-First Search (BFS) method. Depth-First Search follow each stock's whole historical price trajectory.

5. Visualization- Clear, Clustered, Summarized visualization.

Algorithm:

Semi-Temporal Analysis of stock Prices Using Graphs.

Input:

$S = \{S_1, S_2, S_3, \dots, S_m\}$ Set of m stocks

$D = \{d_1, d_2, d_3, \dots, d_n\}$ Set of trading days

$P_{s,d} \rightarrow$ Closing price of stock s on day d

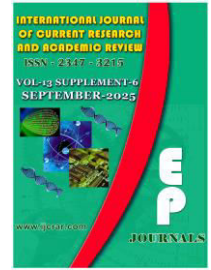


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Output

Semi- temporal graph $G = (V, E)$

BFS traversal results

DFS traversal result

Price Change Calculation

For each stock $s \in S$ and each day $d \in D$ where $d \geq 2$:

$$\Delta P_{s,d} = P_{s,d-1}$$

$$S_{s,d} = \begin{cases} + & \text{if } \Delta P_{s,d} > 0 \\ - & \text{if } \Delta P_{s,d} < 0 \\ 0 & \text{if } \Delta P_{s,d} = 0 \end{cases} \text{ where } +1(I), -(D), 0(N)$$

Graph Construction

Define a directed semi-temporal graph:

$$G = (V, E)$$

$V = \{v_{s,d} / s \in S, d \in D\} \rightarrow$ Each node represents stock day d

$E = \{(v_{s,d} \rightarrow v_{s,d+1}) / s \in S, 1 \leq d < n\} \rightarrow$ Directed edges represent between consecutive days.

BFS Traversal

$BFS(v_{s,1}) = \begin{cases} \text{Visit nodes level by level} \\ S_{s,d} \text{ Compare states across all stocks for each day} \end{cases}$

BFS is used to identify similar price behaviours among different stocks on the same day.

DFS Traversal

$DFS(v_{s,1}) = \begin{cases} \text{Respectively visit } (v_{s,d} \rightarrow v_{s,d+1}) \\ \text{Trace complete price path from 1 to Day } n \end{cases}$

DFS is used for Stocks long term price transitions analyse

$$Color(V_{s,d}) = \begin{cases} GREEN & \text{if } S_{s,d} = + \\ RED & \text{if } S_{s,d} = - \\ GRAY & \text{if } S_{s,d} = 0 \end{cases}$$

Time constraint on n-day traversal



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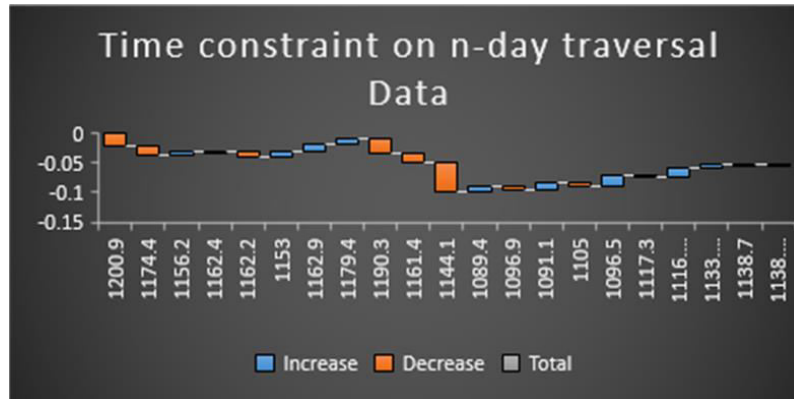


Figure:2.2 Trend line for 10 stock and 20 closing prices

The Semi-temporal graph created using the closing prices of many equities is displayed in Figure 2.2. The stock price on a given day is represented by each node, and the transitions between days are represented by directed edges. Prices rises are represented by green nodes, price reductions by red nodes, no change is represented by blue nodes. Larger datasets like 10 stocks and 200 days) yield more complicated structures that require cluster-wise representation for better comprehension, whereas smaller datasets like 5 stocks and 5 days generate a simple and straightforward graph.

Graph-Based Semi-Temporal Stock Price Analysis Using BFS and DFS Traversal

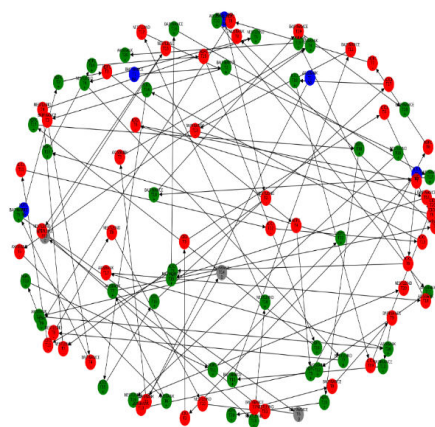


Figure 2.3 Semi-Temporal graph using BFS and DFS large data



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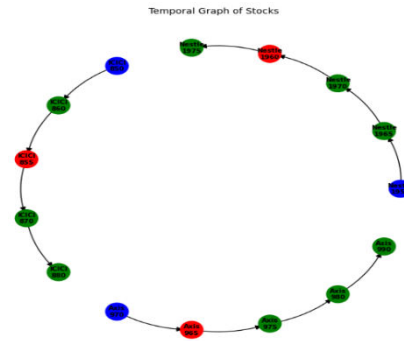


Figure 2.4 Semi- Temporal graph using small data

Conclusion

In this study, we analysed the n-day closing price of taking ten stocks and twenty closing for different sector using Semi-Temporal graph. Each day's price change was represented as +(increase), -(decrease), or 0(no change). Using this approach, we were able to clearly visualize stock price movements and trends.

We applied BFS to compare stock behaviours day by day and DFS to trace the complete price path of each stock. This method makes it easier to understand stock patterns and provides a simple way to study price transitions.

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Full Length Article

IJCRAR/FL/84

An Algorithmic Approach to Reciprocal Domination for Water Conservation

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Abstract

We have introduced the concept of reciprocal domination, a specific type of dominating set D where every vertex in D has at least one neighbouring vertex $p \notin D$ that is dominated by q . We have determined the reciprocal domination number for some specific graphs, and propose an algorithm for calculating this reciprocal domination number and is denoted as ρ . We apply this concept to the optimization of public water conservation in a specific region.

Keywords: Reciprocal domination, Domination Set, Reciprocal domination number, Water conservation, Resource allocation

Introduction

The concept of reciprocal domination, a unique form of a dominating set that emphasizes mutual dependency in networks are discussed. We introduce a new algorithm for calculating the reciprocal domination number in various graph types, including hypercube, binary tree, and complete graphs. We will demonstrate the practical application of this work by using our model to optimize public water conservation. Our findings offer a novel framework for enhancing network resilience and efficiency in real-world systems.



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Literature Review

The study of domination in graphs was formally initiated by Ore and Berge in the late 1950s and early 1960s. Since then, numerous variations have emerged, including total domination, connected domination, and inverse domination. The concept of reciprocal domination builds upon this foundation, exploring a more complex relationship where dominated vertices also exert influence. Our work extends the foundational research of prominent graph theorists by applying these concepts to solve real-world problems. By using the concept of Reciprocal domination, we discussed the following theorems.

Theorem 1: For any hypercube graph Q_n with $n \geq 2$, the reciprocal domination number is 2^{n-1} .

Proof: Let V be the set of vertices in Q_n . Each vertex $v \in V$ can be represented as a binary string of length n . Let v_i denote the i^{th} bit of the string for vertex v . We define a dominating set D as the set of all vertices with an odd number of 1s.

$$D = \{v \in V : \sum_{i=1}^n v_i \equiv 1 \pmod{2}\}$$

We define the set of all other vertices as U

$$U = V \setminus D = \{v \in V : \sum_{i=1}^n v_i \equiv 0 \pmod{2}\}$$

To prove that D is a dominating set, we must show that for every vertex $u \in U$, there exists a vertex $v \in D$ such that v is adjacent to u . For any $u \in U$, there exists a neighbour $v \in D$, which proves that D is a dominating set. To prove that D is a reciprocal dominating set, we must show that for every vertex $v \in D$, there exists a neighbour $u \in U$ such that u is dominated by v . Let $v \in D$. By definition, v has an odd number of 1s. The degree of every vertex in Q_n is n . Since $n \geq 2$, every vertex has at least two neighbours. For every $v \in D$, there exists an adjacent vertex $u \in U$ that is dominated by v , which proves that D is a reciprocal dominating set. The number of vertices in Q_n is 2^n . Therefore, the size of our set D is $|D| = \frac{2^n}{2} = 2^{n-1}$.

Theorem 2 : The reciprocal domination number for any complete graph K_n is 1.

Proof: Let $G=K_n$ be a complete graph with n vertices, where $n \in \mathbb{N}$ and $n \geq 1$. A complete graph is a graph in which every pair of vertices is connected by an edge.

We need to find the smallest set $D \subseteq V$ that is a reciprocal dominating set. We propose a set D containing just one vertex, say v . Let $D=\{v\}$.



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Every vertex in $V \setminus D$ is adjacent to the vertex $v \in D$. This proves that $D = \{v\}$ is a dominating set. v is adjacent to every vertex in $V \setminus \{v\}$, and since v dominates all of these vertices, the condition for reciprocity is met.

Since A set with a single vertex satisfies all the conditions, it is the smallest possible reciprocal dominating set. Therefore, the reciprocal domination number for a complete graph is 1.

Theorem 3: The reciprocal domination number for any binary tree graph is n , where n is an element of the natural numbers ($n \in \mathbb{N}$).

Proof: Let T be a binary tree. A binary tree is a rooted tree where each vertex has at most two children. We need to identify a reciprocal dominating set and prove that its size is the minimum possible. Let's consider the set of all leaf nodes in the binary tree as our candidate dominating set. Let this set be D . A leaf node is a vertex with a degree of 1. The set of all leaf nodes D is a dominating set.

For every vertex v in D , there exists a neighbor u not in D that is dominated by v . This proves that D is a reciprocal dominating set. In a tree, every non-leaf node must be dominated by a leaf node. It is impossible to form a smaller dominating set because each leaf node can only dominate one vertex, which is its immediate neighbor. Therefore, the reciprocal domination number for any binary tree graph is equal to the number of leaf nodes, which can be represented as n .

Theorem 4: The reciprocal domination number for any wheel graph W_n with $n \geq 4$ is 2.

Proof: A wheel graph W_n is formed by connecting a single central vertex, called the hub, to all vertices of an outer cycle graph C_{n-1} . The total number of vertices in W_n is n .

We define a candidate dominating set D as the set containing the central vertex (the hub), which we'll call h , and any single vertex from the outer cycle, which we'll call v . So, $D = \{h, v\}$.

For the hub $h \in D$, it is adjacent to all $n-1$ vertices on the outer cycle. Since $n \geq 4$, there are at least three vertices on the cycle, and at least two of these vertices are not in D . Therefore, h has a neighbor not in D that it dominates. For the vertex $v \in D$ on the outer cycle, it has a neighbor on the cycle not in D , and it is also adjacent to the hub h . Since $h \in D$ and v is on the outer cycle, the neighbors of v on the cycle are not in D and are dominated by v . Therefore, a minimum reciprocal dominating set for a wheel graph W_n is of size 2.



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Theorem 5 : The reciprocal domination number for a circular ladder graph CL_n is $\lceil n/2 \rceil$.

Proof: A circular ladder graph CL_n is a graph formed by two concentric cycles of n vertices, with corresponding vertices on each cycle joined by an edge.

The vertices not in D on the outer cycle (e.g., $v_{1,2}, v_{1,4}, v_{1,i}, v_{1,6}$) are dominated by their neighbours in D . The vertices on the inner cycle (e.g., $v_{2,1}, v_{2,2}, v_{2,6}$) are all dominated because each one is connected to a vertex on the outer cycle, and half of those are in D . This proves that D is a dominating set.

Each vertex in D has a neighbour not in D that it dominates. A vertex $v_{1,i}$ in D has two neighbours on the outer cycle that are not in D , and a neighbour on the inner cycle that may or may not be in D . They have at least one neighbour outside of the set, and the set dominates all the nodes outside the set, so the condition holds. Therefore, our set D is a reciprocal dominating set. The size of our set is $\lceil n/2 \rceil$.

Theorem 6 : For a complete bipartite graph $K_{m,n}$ with $m, n \geq 2$, the reciprocal domination number is 2.

Proof:

A complete bipartite graph $(K_{m,n})$ is a graph whose vertices can be divided into two disjoint and independent sets, U and V , such that every vertex in U is connected to every vertex in V . There are no edges within U or within V . The total number of vertices is $m+n$.

Let's choose a set D consisting of two vertices, one from each partition. Let $u \in U$ and $v \in V$. Thus, $D = \{u, v\}$.

For the vertex $u \in D$, it is connected to all n vertices in V . Since $n \geq 2$, at least one vertex in V is not in D and is dominated by u . For the vertex $v \in D$, it is connected to all m vertices in U . Since $m \geq 2$, at least one vertex in U is not in D and is dominated by v . Both vertices in D have neighbors outside of D that they dominate. Thus, D is a reciprocal dominating set.

We have a reciprocal dominating set of size 2.

Applying Reciprocal Domination to Chennai's Water Network

This model categorizes areas as primary hubs (Velachery, Sholingnallur, Alandur, Mylapore, and Ambattur), dependent areas (such as Perambur and Egmore), or mixed cases (like Tondiarpet and Mambalam) that have both internal resources and external needs. The



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approach helps urban planners determine the optimal number of hubs to build a resilient and robust water supply system.

Algorithm for Chennai Water Network Analysis

```
FUNCTION AnalyzeChennaiNetwork()
// Initialize Chennai area data
AreaData = InitializeChennaiAreas()
// Build network graph
G = BuildNetwork(Areas, AreaData)
// Find optimal hub configuration
OptimalHubs = FindMinimalRDS(G, AreaData)
// Calculate dominated areas
DominatedAreas = ∅
FOR each hub IN OptimalHubs DO
    DominatedAreas = DominatedAreas ∪ Neighbors(hub)
END FOR
DominatedAreas = DominatedAreas - OptimalHubs
// Compute results and display
Results = {
    reciprocal_domination_number: |OptimalHubs|,
    conservation_hubs: OptimalHubs,
    dependent_areas: DominatedAreas,
    hub_efficiency: |OptimalHubs| / |Vertices(G)|,
    coverage: (|OptimalHubs| + |DominatedAreas|) / |Vertices(G)|
}
PRINT "Conservation Hubs:", OptimalHubs
PRINT "Dependent Areas:", DominatedAreas
PRINT "Hub Efficiency:", Results.hub_efficiency
RETURN Results
END FUNCTION
```

Conclusion:

This paper discusses a novel framework for analyzing network dependencies through the concept of reciprocal domination. By developing a new algorithm and demonstrating its



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application in public water conservation, our findings underscore the practical utility of this approach. This model provides a foundation for future research aimed at enhancing resilience and optimizing resource allocation in diverse real-world systems.

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Full Length Article

IJCRAR/FL/85

Neural Network Models for Cursive and Complex Handwriting Recognition

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Abstract

Handwriting recognition has become a pivotal research area in artificial intelligence due to the inherent variability and complexity of handwritten text, particularly cursive and stylistically diverse scripts. Traditional methods such as template matching and handcrafted feature extraction often failed to address these challenges effectively. The advent of neural networks has transformed this domain by enabling automated feature learning and robust sequence modeling. Convolutional Neural Networks (CNNs) excel at spatial feature extraction, while Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) architectures effectively model sequential dependencies. More recently, Transformer-based models have demonstrated superior performance by capturing global contextual relationships, making them highly suitable for complex and multilingual handwriting recognition. Hybrid architectures that combine CNNs, RNNs, and Transformers further enhance recognition accuracy, particularly for connected cursive scripts. Applications of these techniques span across OCR systems, signature verification, historical manuscript preservation, and multilingual document processing. However, challenges remain, including variability in writing styles, limited datasets, noise in input images, and high computational costs. Recent innovations such as data augmentation, cross-lingual transfer learning, and explainable AI offer promising solutions. Looking ahead, advancements in real-time recognition, edge deployment, and cross-lingual systems will expand the accessibility and reliability of handwriting recognition technologies.

Keywords: Handwriting Recognition, Neural Networks, Convolutional Neural Networks (CNN)

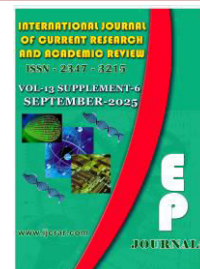


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Introduction

Handwriting recognition has emerged as a critical area in artificial intelligence, particularly due to the complexities of cursive and stylistically diverse scripts. Unlike printed text, handwritten data exhibits high variability, making conventional pattern recognition techniques insufficient. Neural network models have revolutionized this domain by providing robust feature extraction and sequence learning capabilities. This paper reviews state-of-the-art neural network techniques for recognizing complex handwriting and explores their applications, innovations, and future prospects.

Historical Background

Early handwriting recognition relied on template matching, statistical pattern recognition, and handcrafted feature extraction. While these methods achieved moderate success for printed text, they struggled with cursive handwriting and mixed scripts. With the development of machine learning, particularly neural networks, handwriting recognition saw significant improvements.

The introduction of Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) enabled automated feature extraction and sequence learning, paving the way for accurate cursive text recognition.

Neural Network Models For Handwriting Recognition

CNNs are widely used for image-based handwriting recognition, capturing spatial hierarchies and invariant features. RNNs and LSTM handle sequential data effectively, learning long-range dependencies, crucial for connected cursive handwriting. Transformers, employing attention mechanisms, learn global dependencies and contextual relationships, suitable for complex scripts and multilingual recognition. Hybrid models combining CNNs with RNNs or Transformers have shown improved recognition accuracy, especially for cursive and connected handwriting.

Applications

OCR: Digitizing handwritten documents into editable text.



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Signature Verification: Authenticating signatures for banking and legal applications.

Historical Manuscripts: Preserving and digitizing ancient handwritten texts.

Multilingual Recognition: Recognizing different scripts within the same document.

Challenges And Limitations

Variability in Handwriting Styles: Each person writes uniquely.

Noise and Quality Issues: Scanned or photographed text can have distortions.

Dataset Scarcity: Limited labeled datasets for complex scripts.

Computational Cost: Deep networks require significant resources for training and inference.

Innovations / Novelty

Hybrid Neural Network Models: CNN-RNN or CNN-Transformer models provide higher accuracy for connected scripts.

Data Augmentation: Synthetic data generation improves recognition for rare handwriting styles.

Explainable AI: Visualizing attention or feature maps to understand model decisions.

Cross-Language Transfer Learning: Models trained on one script adapted to others with limited data.

Future Directions

Real-Time Handwriting Recognition: Mobile and tablet-based solutions for instant transcription.

Integration with Education Tools: AI for automatic grading, feedback, and handwriting improvement.

Historical and Rare Script Preservation: Digitizing endangered scripts.

Cross-Lingual Models: Unified AI systems recognizing multiple languages.

Edge AI Deployment: Lightweight models for faster processing on devices.



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Conclusion

Neural networks have significantly enhanced cursive and complex handwriting recognition, overcoming challenges that traditional methods could not. Hybrid models combining CNNs, RNNs, and Transformers have shown high accuracy, enabling applications ranging from OCR to historical document preservation. Continued research in real-time processing, multilingual recognition, and explainable AI will drive future advancements, making handwriting recognition more accessible and reliable.

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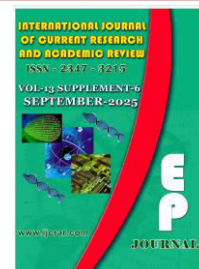


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Full Length Article

IJCRAR/FL/86

Acinetobacter baumannii: An Emerging Foodborne and Multi-Drug-Resistant Pathogen

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Abstract

Acinetobacter baumannii has transitioned from being primarily a hospital-acquired pathogen to an emerging global threat spanning clinical, environmental, and food chain settings. In intensive care units, it remains a major cause of pneumonia, septicemia, meningitis, and wound infections, with high morbidity and mortality linked to its multidrug resistance (MDR). Recent surveillance in India confirms the predominance of isolates displaying extensive resistance to β -lactams, aminoglycosides, fluoroquinolones, and tetracyclines in lower respiratory tract infections, while retaining susceptibility only to colistin and polymyxin B. Beyond hospitals, studies from South Africa have demonstrated that abattoirs and aquatic environments harbor MDR *A. baumannii*, with over half of the isolates resistant to carbapenems and carrying blaOXA-23 or blaOXA-58 genes, underscoring the potential for extra-hospital dissemination. Increasingly, the organism is also being recovered from raw meat, poultry, dairy products, and vegetables in countries such as Saudi Arabia, India, and Iran, with prevalence rates ranging from 20% to 46%. Food-derived isolates often carry biofilm-associated and resistance genes including ompA, bap, csuE, and blaPER-1, contributing to persistence and environmental survival. Although resistance levels in some food isolates are lower than those observed in clinical strains, their detection in community food sources raises concern for horizontal transfer of MDR determinants. Collectively, these findings highlight the remarkable adaptability of *A. baumannii*, its capacity to bridge hospital, environmental, and foodborne reservoirs, and the urgent need for standardized detection methods, strict hygienic practices in food production, and coordinated global surveillance to prevent further dissemination into both community and healthcare settings.

Keywords: *Acinetobacter baumannii*, Multidrug resistance (MDR), Carbapenems, Food chain contamination, Environmental reservoirs

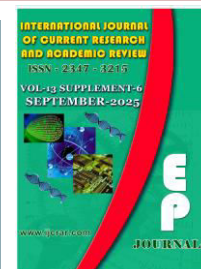


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Introduction

Acinetobacter baumannii has transitioned from being a hospital-associated bacterium to a globally relevant pathogen with evidence of occurrence in food sources. Traditionally linked to ventilator-associated pneumonia, septicemia, and meningitis (Almasaudi, 2018; Askari et al., 2019), *A. baumannii* has been classified by the World Health Organization (WHO) and Centers for Disease Control and Prevention (CDC) as a critical-priority pathogen due to its carbapenem resistance (Novovic et al., 2015; Poirel & Nordmann, 2006). Increasing reports from Saudi Arabia, India, and Iran confirm its presence in raw meat and poultry (Elbehiry et al., 2021; Kumar et al., 2021; Askari et al., 2020). Other studies have identified it in vegetables and milk (Berlau et al., 1999; Gurung et al., 2013; Zhang et al., 2014). Its emergence in the food chain highlights the importance of adopting a One Health framework linking human, animal, and environmental health (Carvalho et al., 2016).

Epidemiology and Foodborne Occurrence

Epidemiological investigations show regional variation in the prevalence of *A. baumannii*. In Saudi Arabia, it was isolated from 46.5% of sheep, 32.5% of chicken, 15% of cow, and 9.7% of camel meat (Elbehiry et al., 2021). Iranian studies found prevalence rates of 20.1%, highest in ovine meat (32.1%) and lowest in turkey (11.1%) (Askari et al., 2020). In India, four isolates were identified from 50 chicken meat and environmental samples (Kumar et al., 2021). Similar findings of foodborne occurrence have been reported in Nepal (Bantawa et al., 2018) and China (Zhang et al., 2014). These results indicate *A. baumannii* is no longer restricted to hospital environments but is present in retail food sources worldwide.

Isolation and Identification Methods

Isolation typically begins with culture on selective media such as MacConkey or ChromID agar, followed by biochemical tests including oxidase, citrate, urease, indole, and motility assays (Askari et al., 2020; Elbehiry et al., 2021). Molecular confirmation has become increasingly important, using PCR, qPCR, and loop-mediated isothermal amplification (Soo et al., 2013). Proteomic approaches such as MALDI-TOF MS allow rapid and accurate species-level identification (Espinal et al., 2012; Marí-Almirall et al., 2019). Biofilm detection is frequently conducted using crystal violet microtiter assays (Toledo-Arana et al., 2001).

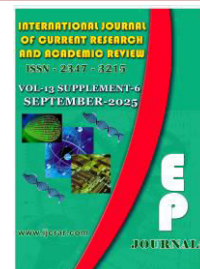


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Virulence Factors and Biofilm Formation

Virulence is closely linked to biofilm formation, enabling *A. baumannii* to persist in harsh environments and on food-contact surfaces. Genes such as *ompA*, *bap*, *csuE*, and *blaPER-1* play critical roles in adherence, biofilm stability, and antibiotic resistance (Fattahian et al., 2011; Avila-Novoa et al., 2019; Brossard & Campagnari, 2012; Loehfelm et al., 2008). The capacity for biofilm formation has been linked to increased multidrug resistance (Lee et al., 2008). These mechanisms explain its survival in food processing and hospital environments alike.

Antimicrobial Resistance Mechanisms

Antimicrobial resistance is a defining characteristic of *A. baumannii*. Saudi isolates displayed resistance to amoxicillin-clavulanic acid (89.1%), gentamicin (74.5%), and tetracycline (72.7%) (Elbehiry et al., 2021). Iranian isolates showed resistance to gentamicin (87.2%), tetracycline (79.5%), erythromycin (74.3%), and azithromycin (66.7%), with lower resistance to imipenem (17.9%) (Askari et al., 2020). Indian isolates, in contrast, showed low resistance profiles (Kumar et al., 2021). Mechanisms include ESBLs, metallo- β -lactamases, and carbapenemases (Fallon & Young, 2007; Saha et al., 2010; Poirel & Nordmann, 2006).

Public Health and One Health Implications

The presence of *A. baumannii* in retail meat suggests a potential pathway for transmission from animals to humans. This highlights the interconnectedness of human, animal, and environmental health, central to the One Health approach (Carvalho et al., 2016). Foodborne isolates share resistance traits with hospital strains, suggesting possible genetic exchange (Novovic et al., 2015). Without coordinated interventions, foodborne dissemination could exacerbate the antimicrobial resistance crisis (WHO, 2017).

Discussion

The detection of *Acinetobacter baumannii* in food samples from different geographical regions indicates that this pathogen is not confined to clinical environments but may have significant reservoirs in the food chain.



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Elbehiry et al. (2021) demonstrated a notably high prevalence of *A. baumannii* in raw meat samples collected in Saudi Arabia, with the highest contamination detected in sheep and chicken meat. Importantly, this study not only confirmed the presence of the organism but also showed that a large proportion of isolates carried biofilm-associated genes such as ompA, bap, csuE, and blaPER-1. The ability to form biofilms was directly associated with increased resistance, especially against aminoglycosides and β -lactams. The use of advanced proteomic tools such as peptide mass fingerprinting (PMF) and MALDI-TOF MS in this study provided highly reliable identification, minimizing misclassification that may occur with traditional biochemical assays.

Askari et al. (2020), working in Iran, reported a prevalence rate of 20.1% in raw meat samples, with ovine meat showing the highest contamination levels. This study emphasized not only phenotypic resistance but also the molecular detection of resistance genes, confirming widespread presence of determinants conferring resistance to gentamicin, tetracycline, and fluoroquinolones. The antimicrobial susceptibility results were alarming: more than 80% of isolates were resistant to gentamicin and nearly 80% to tetracycline, with significant resistance also noted against ciprofloxacin and trimethoprim-sulfamethoxazole. These findings highlight that foodborne *A. baumannii* may serve as a reservoir for multidrug resistance genes, potentially transferable to other bacteria within the food microbiome.

Kumar et al. (2021), in their investigation of retail chicken meat in North India, detected *A. baumannii* not only in meat but also in environmental samples such as knives and cutting surfaces. Although the resistance levels in these isolates were lower compared to clinical strains, resistance to macrolides and fluoroquinolones was still recorded. The presence of *A. baumannii* in slaughterhouse environments suggests poor hygienic practices and cross-contamination as major drivers for dissemination into food products. The study also highlighted the role of MALDI-TOF MS in improving accuracy of identification, reflecting a convergence with findings from Elbehiry et al. (2021).

From a broader perspective, Amorim and Nascimento (2017) reviewed the significance of *A. baumannii* in extra-hospital environments, including dairy products and vegetables. Their analysis suggested that the persistence of *A. baumannii* outside healthcare facilities is facilitated by biofilm formation, desiccation resistance, and genetic plasticity. These features allow the

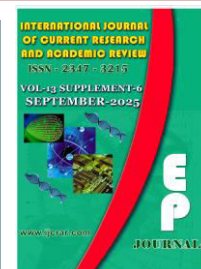


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bacterium to survive food-processing and storage conditions, positioning it as an underestimated foodborne pathogen.

Together, these results demonstrate that *A. baumannii* in food systems is not merely a contaminant but a carrier of virulence factors and resistance genes. The studies collectively underline the urgent need for global surveillance, standardized methodologies for detection, and strict food safety practices to prevent transmission of MDR strains from food to humans.

Conclusion

Acinetobacter baumannii is no longer confined to hospitals but is increasingly identified in food sources, particularly raw meat. Its virulence genes, biofilm-forming ability, and antibiotic resistance determinants enhance its persistence and pathogenicity. The combined evidence from Saudi Arabia, Iran, and India highlights both high prevalence and alarming resistance profiles. Standardized surveillance methods, strict hygiene in slaughterhouses, and continuous monitoring of resistance genes are essential. Considering its inclusion on the WHO critical priority list, proactive integration of food safety and public health strategies is urgent to prevent its spread into healthcare and community settings.

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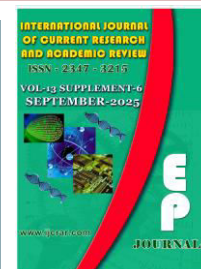


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Full Length Article

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Isolation of Pigment Producing Actinomycetes from Rhizosphere Soil, Extraction and Characterisation of Pigments and Application in Textile Industry

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Abstract

Biological pigments are of worldwide interest due to their low production cost and eco – friendly nature. Biological pigments are extracted from plants and from microbes. Microorganisms are considered as potential source over plants because microbes have rapid multiplication rates, easy cultivation in low-cost media, can be grown and extracted independent of weather conditions and microbial pigments can be processed easily with simple techniques. There is high demand for microbial pigments in the global market and find applications in food industries, pharmaceutical industries, textiles and cosmetics industries. Microbial pigments have a broad spectrum of biological activities such as antibiotic, antimicrobial, antioxidant, and antitumor. With rising demands for biological pigments over synthetic colorants, there is a lot of work tending towards the extraction and identification of pigments from microorganism. Actinomycetes can synthesize a wide range of dark pigments referred to as melanin/melanoid pigments, some well-established pigments from actinomycetes are-blue (*Streptomyces coelicolor*), brown (*Streptomyces* sp.), green (*Actinomyces viscosus* and *Saccharomonospora viridis*), orange (*A.naeslundii*), red (*Streptomyces echinoruber*), violet (*Streptomyces mauvecolor*), yellow (*Streptomyces hygroscopicus*), etc. Due to the above-mentioned reasons, the present study will discuss about isolating and identifying pigment producing actinomycete from rhizosphere soil on Starch casein agar/ Actinomyces isolation agar, molecular identification by 16 S rRNA studies, extraction of pigments by bioassay guided fractionation, evaluation of the isolated pigment for antimicrobial activity and the potential application of the pigment in textile dying especially in textile used for medical application.

Keywords: Microbial pigments, Melanin, Actinomycetes, Streptomyces

Introduction

The textile industry had long relied on synthetic dyes derived from petrochemical sources, which contributed significantly to environmental degradation. These dyes often contained hazardous substances such as heavy metals and aromatic amines, which posed risks

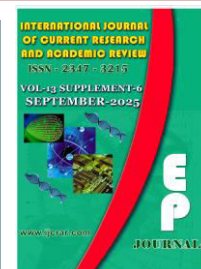


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to both human health and aquatic ecosystems (Kumar et al., 2020; Singh et al., 2019). As awareness of these issues increased, researchers began exploring natural alternatives that could offer safer and more sustainable solutions.

Among various microbial sources, actinomycetes emerged as promising candidates for pigment production. These filamentous, Gram-positive bacteria demonstrated remarkable metabolic diversity and were capable of synthesizing a wide range of secondary metabolites, including bio-pigments with antimicrobial, antioxidant, and UV-protective properties (Ramesh et al., 2021; Sharma & Dutta, 2022). Their pigments not only provided vibrant coloration but also enhanced the functional performance of textiles, making them suitable for specialized applications such as medical fabrics and outdoor gear.

This review aimed to examine the potential of pigment-producing actinomycetes, focusing on their isolation, extraction, characterization, and application in textile dyeing. It also addressed the comparative advantages of microbial pigments over synthetic dyes and discussed the challenges and future directions for scaling up their production.

Literature Review:

Rhizospheric Actinomycetes as Pigment Producers

Researchers had identified the rhizosphere as a rich microbial niche, particularly effective for isolating pigment-producing actinomycetes. Soil samples collected from plant root zones yielded strains such as *Streptomyces* spp., which exhibited vibrant pigmentation and bioactivity (Ramesh et al., 2021; Sharma & Dutta, 2022). These organisms thrived in nutrient-dense environments and demonstrated high metabolic potential for secondary metabolite production.

Isolation and Screening Approaches

Isolation techniques had typically involved serial dilution and plating on selective media like ISP-2 and starch casein agar. Pigment-producing colonies were screened based on visible coloration and antimicrobial zones against test organisms (Kumar et al., 2020). Bioactivity

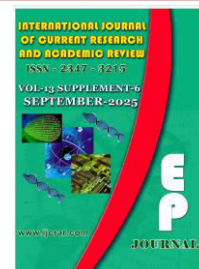


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assessments were conducted using agar well diffusion and disc diffusion methods, confirming the dual functionality of the pigments.

Extraction and Purification Techniques

Pigments were extracted using organic solvents such as methanol, ethanol, and acetone, with methanol often yielding the most stable and concentrated extracts (Singh et al., 2019). Purification was achieved through thin-layer chromatography (TLC) and column chromatography, which allowed for the separation of distinct pigment fractions for further analysis.

Characterization of Pigments

Spectroscopic and chromatographic methods had been employed to characterize the pigments. UV-Vis spectroscopy confirmed absorbance peaks, while FTIR analysis revealed functional groups. High-performance liquid chromatography (HPLC) and gas chromatography-mass spectrometry (GC-MS) provided insights into pigment purity and molecular composition (Ramesh et al., 2021).

Textile Dyeing Applications

Pigments derived from actinomycetes had been successfully applied to natural fabrics such as cotton and silk. These treated textiles demonstrated strong colour retention, antimicrobial activity, and UV resistance, making them suitable for medical and outdoor use (Sharma & Dutta, 2022). Unlike synthetic dyes, these microbial pigments were biodegradable and non-toxic.

Advantages Over Synthetic Dyes

Microbial pigments offered several benefits over synthetic counterparts, including renewability, safety, and multifunctionality. Synthetic dyes had been associated with allergic reactions and environmental hazards, whereas pigments from actinomycetes provided eco-friendly and health-conscious alternatives (Kumar et al., 2020).

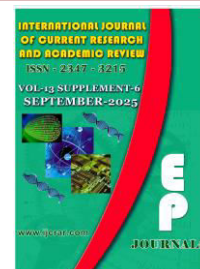


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Challenges and Future Directions

Despite their promise, microbial pigments faced limitations in terms of scalability, consistency, and regulatory acceptance. Researchers had suggested optimizing fermentation conditions and exploring genetic engineering to enhance pigment yield and stability. Future studies were expected to focus on cost-effective production and industrial integration (Singh et al., 2019).

Discussion:

Biological Potential of Actinomycetes

Actinomycetes had demonstrated remarkable biosynthetic capabilities, producing a wide range of secondary metabolites, including pigments with therapeutic and industrial relevance. Their ability to generate structurally diverse compounds had made them a focal point in microbial biotechnology. The production of pigments such as melanin, prodigiosin, and violacein had been linked to their adaptive responses to environmental stress, suggesting a natural resilience that could be harnessed for sustainable dyeing processes.

Functional Enhancement of Textiles

Textiles treated with actinomycete-derived pigments had shown enhanced performance characteristics. In addition to coloration, fabrics exhibited antimicrobial activity, UV protection, and reduced odor retention. These properties had been particularly valuable in medical textiles, sportswear, and outdoor gear. The integration of bio-pigments into textile substrates had offered a dual advantage – visual appeal and functional utility – without relying on synthetic additives.

Environmental and Economic Implications

The shift from synthetic dyes to microbial pigments had been driven by environmental concerns and the rising demand for sustainable products. Synthetic dyes contributed to water pollution, bioaccumulation, and toxicity in aquatic ecosystems. In contrast, pigments from actinomycetes were biodegradable and produced under mild conditions, reducing the ecological

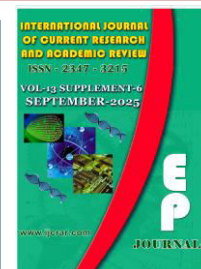


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footprint of textile manufacturing. Economically, microbial dyeing had the potential to lower long-term costs by minimizing effluent treatment and regulatory penalties.

Challenges in Process Optimization

Despite their promise, microbial pigment production had faced several technical challenges. Yield variability among strains, sensitivity to culture conditions, and pigment instability during storage had limited scalability. Fermentation parameters such as pH, temperature, and carbon source had required fine-tuning to achieve consistent output. Moreover, downstream processing—including extraction and purification—had added complexity and cost to the workflow.

Advances in Genetic and Metabolic Engineering

Recent advances in genetic engineering had opened new avenues for enhancing pigment production. Techniques such as CRISPR-Cas9 and metabolic pathway reconstruction had enabled researchers to increase yield, modify pigment structure, and introduce novel color variants. These innovations had the potential to overcome natural limitations and make microbial dyeing more commercially viable.

Industrial Integration and Future Outlook

For microbial pigments to be adopted at scale, integration into existing textile workflows had been essential. Compatibility with dyeing machinery, stability under washing and light exposure, and regulatory approval had emerged as key factors. Collaborative efforts between microbiologists, textile engineers, and industry stakeholders were expected to accelerate the transition toward bio-based dyeing. Future research was likely to focus on pilot-scale production, cost reduction strategies, and consumer acceptance.

Conclusion:

Pigment-producing actinomycetes had emerged as promising candidates for sustainable textile dyeing, offering an eco-friendly alternative to synthetic dyes. Their ability to synthesize



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bioactive pigments with antimicrobial, antioxidant, and UV-protective properties had added functional value to fabrics, particularly in medical and outdoor applications. The rhizosphere had served as a rich source for isolating potent strains, while advancements in extraction and characterization techniques had enabled deeper insights into pigment composition and performance.

Despite these achievements, challenges related to scalability, pigment stability, and regulatory approval had limited industrial adoption. However, ongoing research in genetic engineering, fermentation optimization, and green processing methods had shown potential to overcome these barriers. With continued interdisciplinary collaboration and investment in biotechnological innovation, microbial pigments from actinomycetes could play a pivotal role in transforming the textile industry toward a more sustainable and health-conscious future.

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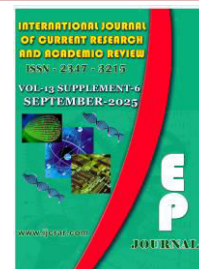


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Full Length Article

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Dust Free, Biodegradable Chalk Piece Using Microbial Pigments

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Abstract

Conventional chalk, composed of synthetic calcium carbonate, is recognized as a source of classroom dust that contributes to respiratory discomfort and occupational health concerns among teachers and professors. Prolonged exposure to such particles has been associated with irritation of the respiratory tract, allergic responses, and increased occupational risk over time. Furthermore, reliance on chemically processed calcium carbonate raises concerns regarding environmental sustainability and long-term waste accumulation. In this context, biodegradable and dust-free chalk is discussed as an alternative. Eggshells, naturally rich in calcium carbonate, represent a promising substitute that not only reduces dependence on synthetic raw materials but also supports waste valorization by transforming discarded shells into useful classroom products. Gum arabic is considered as a natural binder that can provide cohesion, mechanical stability, and effective reduction of dust release, thereby ensuring safer handling. Microbial pigments are highlighted as natural and non-carcinogenic alternatives to synthetic dyes. Violacein from *Chromobacterium violaceum*, prodigiosin from *Serratia marcescens*, and pyocyanin from *Pseudomonas aeruginosa* are particularly noted for their vivid coloration and reported bioactive properties. Previous studies describe their recovery through fermentation, extraction, and purification, illustrating feasible approaches that could be adapted for classroom materials. Beyond coloration, these pigments may also contribute antimicrobial benefits, thereby enhancing overall safety. Taken together, these considerations suggest the potential of developing chalk that integrates reduced dust generation, biodegradability, and safe pigmentation. Consequently, this concept reflects the broader aim of merging microbial biotechnology with sustainable waste management, thereby advancing environmentally responsible innovations for classroom use.

Keywords: Biodegradable chalk, Microbial pigments, Violacein, Prodigiosin, Pyocyanin, Gum arabic.

Introduction

For centuries, chalk has been one of the most widely used educational tools. Before the arrival of whiteboards and digital technology, it served as the universal medium of knowledge



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transmission. Its affordability, ease of use, and reusability made it indispensable worldwide. Chalk was initially obtained from limestone deposits, but the rapid expansion of education in the nineteenth and twentieth centuries led to the adoption of artificially synthesized calcium carbonate. While this ensured large-scale production, it also introduced health and environmental drawbacks (Singh et al., 2019).

A major concern with synthetic chalk is the generation of fine dust particles. Many fall within the respirable range, reaching the lungs and causing coughing, throat irritation, rhinitis, or worsening of asthma and bronchitis. Teachers and students in poorly ventilated classrooms face the greatest risks (Sharma & Yadav, 2017; Singh et al., 2015). Chalk dust is now considered an occupational hazard for educators.

Environmental costs add further challenges. Producing synthetic calcium carbonate requires limestone calcination, which consumes significant energy and releases CO₂. Chalk residues are also non-biodegradable, accumulating in landfills (Singh et al., 2019). Such practices conflict with global sustainability goals, including the UN SDGs.

To overcome these issues, biodegradable dust-free chalk has emerged as an alternative. Eggshells, composed primarily of crystalline calcium carbonate, can be sterilized and processed into powders suitable for chalk (Laohavisuti et al., 2021). This valorization reduces waste and supports circular economy principles.

Coloration, traditionally achieved with synthetic dyes, also raises toxicity and carcinogenicity concerns (Choi et al., 2020). Microbial pigments such as violacein, prodigiosin, and pyocyanin provide vivid natural colors while offering antimicrobial and antioxidant benefits (Durán et al., 2012; Mendhulkar & Balaji, 2012; Silva et al., 2021). Unlike synthetic dyes, they degrade without harmful residues, improving ecological and classroom safety. Thus, integrating eggshell-derived calcium carbonate, gum arabic, and microbial pigments represents more than substitution. It combines microbiology, waste management, and occupational safety, offering a sustainable classroom innovation.



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Literature Review

Biodegradable Alternatives : Eggshell-Derived Calcium Carbonate

Eggshells, widely generated as waste, are over 95% crystalline calcite with trace magnesium and proteins. Once sterilized and ground, they can substitute synthetic calcium carbonate in chalk. This reduces waste, lowers costs, and provides an eco-friendly raw material. Unlike chemically precipitated forms, eggshell powders decompose naturally, supporting circular economy practices (Laohavisuti et al., 2021; Singh et al., 2019).

Role of Binders and Additives

Gum arabic, a natural polysaccharide from *Acacia senegal*, is widely used for its binding and dust-reducing properties (Whistler & BeMiller, 1973). Additives such as glycerol and starch improve flexibility, while oils like neem and sunflower inhibit microbial growth, ensuring durability and classroom safety (Mali & Reddy, 2019).

Microbial Pigments as Natural alternatives to Synthetic dyes

Synthetic dyes are poorly biodegradable and sometimes carcinogenic (Choi et al., 2020). Microbial pigments provide safer, multifunctional alternatives. Violacein from *Chromobacterium violaceum* has antimicrobial and antioxidant benefits (Silva et al., 2021). Prodigiosin from *Serratia marcescens* provides deep red hues with antimicrobial activity (Mendhulkar & Balaji, 2012). Pyocyanin from *Pseudomonas aeruginosa* produces a blue-green shade with additional antimicrobial potential (Heinemann et al., 2020). Other pigments include carotenoids from *Rhodotorula* and *Micrococcus* (Dufossé, 2009), melanin from *Aspergillus* and *Cryptococcus* (Plonka & Grabacka, 2006), and anthraquinones from *Fusarium* and *Streptomyces* (Venil et al., 2013). These have been extracted and tested for use in educational materials.

Biosafety Considerations

Some pigment-producing microbes, including *S. marcescens*, *P. aeruginosa*, and *C. violaceum*, are opportunistic pathogens requiring Biosafety Level 2 handling (Choi et al., 2020).

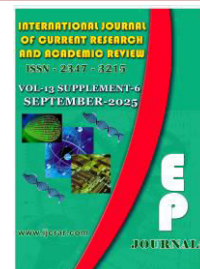


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Purification steps such as heat treatment and microfiltration remove viable cells and endotoxins. Cytotoxicity studies confirm that purified pigments are safe for classroom use (Durán et al., 2012; Silva et al., 2021).

Methodological Insights

Isolation of Pigment-Producing Microbes

Pigment-producing bacteria such as *S. marcescens*, *P. aeruginosa*, and *C. violaceum* are isolated from soil, water, and moist environments. They are identified using selective media such as cetrimide agar or MacConkey agar (Durán et al., 2012; Mendhulkar & Balaji, 2012; Heinemann et al., 2020). Stable pigment production is maintained through subculturing, with long-term storage in glycerol stocks at -80°C .

Pigment Extraction and Purification

Methods vary by pigment: pyocyanin is extracted with chloroform/HCl, prodigiosin with alcohols, and violacein with ethanol or DMSO (Silva et al., 2021). Centrifugation and solvent separation improve purity. Rotary evaporation or vacuum drying concentrates pigments, while spectrophotometry verifies yields (Choi et al., 2020).

Sterilization and Safety Checks

Extracts are sterilized via membrane filtration or low-heat treatment (Choi et al., 2020). Sterility is confirmed through culturing, and cytotoxicity tests ensure safety (Durán et al., 2012; Silva et al., 2021).

Eggshell Processing

Eggshells are cleaned, disinfected, oven-dried, and ground into fine powders (100–200 μm). This produces smooth texture and reduces friability (Laohavisuti et al., 2021). Eggshell valorization ensures a renewable calcium source (Singh et al., 2019).



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Chalk Formulation

Chalk paste is prepared from calcium carbonate, gum arabic, pigments, and additives. Typical formulations include 80–85% calcium carbonate, 8–12% gum arabic, and 0.2–1% pigment. Plasticizers like starch improve flexibility, while oils prevent microbial growth. Cured sticks are polished and tested for strength, dust suppression, and writing smoothness (Whistler & BeMiller, 1973; Patil et al., 2018).

Discussion

Environmental Sustainability

Synthetic calcium carbonate consumes energy and emits CO₂ (Singh et al., 2019). Eggshell recycling reduces waste and provides renewable calcium. Chalk with natural binders and pigments biodegrades safely, supporting SDG 12 and SDG 13 (Whistler & BeMiller, 1973; Laohavisuti et al., 2021).

Health Implications

Conventional chalk dust causes respiratory irritation and worsens asthma (Sharma & Yadav, 2017; Singh et al., 2015). Biodegradable chalk lowers dust emissions with gum arabic and safer calcium sources. Studies show nearly 50% less dust release (Patil et al., 2018).

Antimicrobial and Educational Benefits

Microbial pigments add antimicrobial and antioxidant protection (Durán et al., 2012; Choi et al., 2020), preventing microbial growth (Silva et al., 2021). Their vivid colors also enhance engagement and retention (Aslam, 2014).

Classroom Performance

Teachers expect chalk to write smoothly and resist breakage. Biodegradable chalk demonstrates equal or superior strength, reduced brittleness, and vibrant, stable colors



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(Laohavisuti et al., 2021; Patil et al., 2018; Silva et al., 2021). Its eco-friendly identity encourages adoption (Choi et al., 2020).

Conclusion

Biodegradable, pigment-enriched chalk demonstrates how small innovations address global challenges. Repurposing eggshell waste reduces reliance on synthetic resources. Gum arabic ensures strength while minimizing dust, and microbial pigments provide safe, vivid colors with antimicrobial properties. Challenges such as large-scale pigment production, biosafety, and costs remain, but advances in biotechnology offer solutions. Educators and policymakers must recognize both classroom practicality and sustainability benefits. Thus, biodegradable chalk symbolizes responsible consumption, occupational health, and sustainability – showing how modest innovations can deliver significant impacts.

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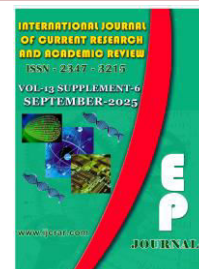


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Full Length Article

IJCRAR/FL/89

Carbon Nano-Encapsulation Preparation for Indoor Gardening

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Abstract

Nanotechnology is one of the most promising technologies of the 21st century. It is the ability to convert the nanoscience theory to useful applications by observing, measuring, manipulating, assembling, controlling, and manufacturing matter at the nanometer scale. Nano fertilizers can reduce the amount of nutrients lost to the environment, improving the efficiency of fertilizer use. Increased crop yields: Nano fertilizer use nanoparticles to deliver phosphorus to crops, improving plant growth and reducing soil pollution. Reduced environmental impact: Nano fertilizers can reduce the amount of nutrients that enter waterways and soil, reducing environmental pollution. Targeted nutrient delivery: Nano fertilizer can be designed to deliver nutrients to specific parts of the plants, improving nutrient use efficiency.

Keywords: Nanopartical, Fertilizer, encapsulation

Introduction

Nanotechnology is one of the most promising technologies of the 21st century. It is the ability to convert nanoscience theory into useful applications by observing, measuring, manipulating, assembling, controlling, and manufacturing matter at the nanometer scale. National Nanotechnology Initiative (NNI) in the United States defines Nanotechnology as “a science, engineering, and technology conducted at the nanoscale (1 to 100 nm), where unique phenomena enable novel applications in a wide range of fields, from chemistry, physics, and biology, to medicine, engineering, and electronics. The first is an issue of scale, nanotechnology is concerned with using structures by controlling their shape and size at the nanometer scale.

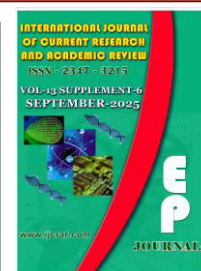


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The second issue is with novelty.

Medicine and Healthcare

Drug delivery: Nanoparticles are used to deliver drugs to specific cells or tissues, reducing side effects and improving efficacy.

Image and Diagnostics: Nanoparticles are contrast agents for imaging techniques such as MRI and CT scans.

Enhanced Nutrient Delivery and Efficiency:

Controlled Release: SWCNTs can act as a controlled-release system, gradually releasing nutrients to the plant roots over time, reducing nutrient loss through leaching, or volatilization.

Targeted Delivery: Encapsulated fertilizers can be delivered directly to the root zone, maximizing nutrient uptake and minimizing wastage.

Improved Fertilizer Use Efficiency: By optimizing nutrient release and targeting delivery, SWCNTs can help improve fertilizer use efficiency, leading to higher crop yields and reduced fertilizer costs.

Seed Germination and Early Growth: SWCNTs have been shown to promote seed germination and early plant growth.

Benefits of nano Fertilizers

Improved nutrients use efficiency: Nano fertilizers can reduce the amount of nutrients lost to the environment, improving the efficiency of fertilizer use.

Increased crop yields: Nano fertilizer use nanoparticles to deliver phosphorus to crops, improving plant growth and reducing soil pollution.

Indoor Gardening Plants

Indoor gardening, also known as indoor horticulture or houseplant cultivation, is the practice of growing plants in an indoor environment, such as a home, office, or apartment.



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Indoor gardens can be created in variety of spaces, from small apartments to large offices, and can be tailored to suit different lifestyles and environments.

Materials and Methods

In indoor gardening plants we use the UV spectrophotometer range for macro and micro nutrients to plant growth. A UV spectrophotometer is an analytical instrument used to measure the absorption of ultraviolet light by molecules.

Preparation of urea ($\text{CO}(\text{NH}_2)_2$) solution:

Using urea as a nitrogen source.

Materials Required: Urea ($\text{CO}(\text{NH}_2)_2$), Distilled water, Balance, Beaker

Preparation of potassium chloride (KCl) solution:

Potassium chloride (KCl) is a commonly used source of potassium.

Materials Required: Potassium chloride (KCl), Distilled water, Balance (for accurate weighing), Beaker (for mixing the solution), 100 mL volumetric flask (for precise volume measurement), Stirring rod or magnetic stirrer (for dissolving).



Fig: Potassium chloride Nutrient Solute



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Preparation of Micronutrients

Micronutrient solutions are essential for providing trace elements that are required in small quantities by plants and for laboratory research in plant nutrition. These micronutrients include elements such as Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), Molybdenum (Mo), and Chlorine

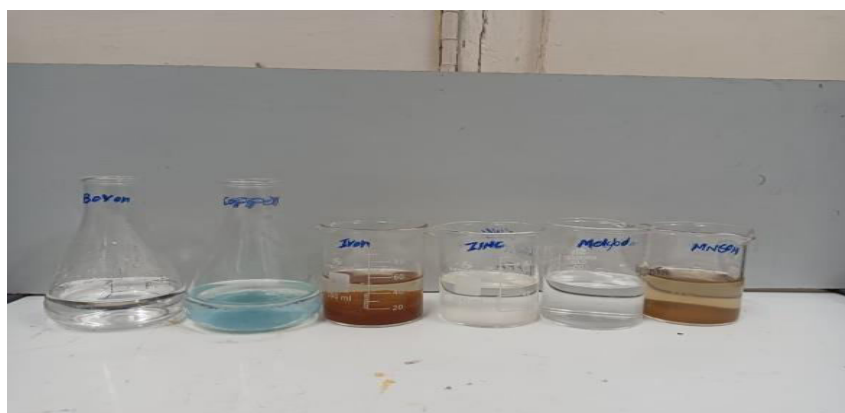


Fig : Micro-nutrients solutions

Carbon Nano-Encapsulation

Carbon nano-encapsulation is a technique used to encapsulate various materials, including drugs, nutrients, or active compounds, within carbon-based nanostructures such as carbon nanotubes (CNTs), graphene, or fullerenes. These encapsulated systems are used in diverse fields such as agriculture, drug delivery, and materials science.

Procedure:

Preparation of Carbon Nanostructures Dispersion

Disperse carbon nanostructures CNTs in a solvent using ultra sonication to break agglomerates and achieve a uniform suspension. Use surfactants if necessary to stabilize the dispersion.

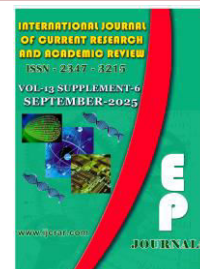


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Purification

Purify carbon nanostructures if needed by acid treatment 1% H₂SO₄ to remove impurities and functionalize the surface. Rinse thoroughly with distilled water until the pH is neutral.

Encapsulation Process

Loading the Active Material. Dissolve or suspend the target compound in a solvent. Add the dispersed carbon nanostructures to the solution.

Results

Macro-Nutrition Capsules



Fig: Nutrient Capsules

Ingredient Selection: Choose the appropriate combination nanoparticles like Urea, Potassium and Phosphate and carbon encapsulation.

Weighing and Mixing: Measure the required amounts of nanoparticle powders. Use a mechanical mixer to create a homogeneous powder blend.

Quality Control Testing:

1. Check capsule weight uniformity.
2. Test for moisture content using a moisture analyzer.
3. Conduct stability tests to ensure shelf-life.



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Storage and Packaging:

Store capsules in light-resistant, airtight containers. Label bottles with nutritional information, dosage, and expiration date.

Preparation of Macronutrients

The successful synthesis of NPK nanoparticles provides an efficient and sustainable alternative to conventional fertilizers. These nanoparticles enhance plant nutrient uptake, reduce pollution, and promote controlled nutrient release for better crop growth

Drying:



Fig: Drying of Nutrients: a) Urea, b) Phosphate and c) Potassium

Preparation of Micronutrition:



Fig: Micro Nutrients: Boron, Copper, Iron, Zinc, Molybdenum, and Manganese

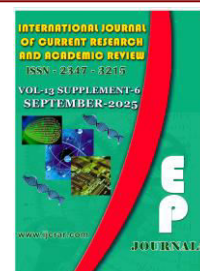


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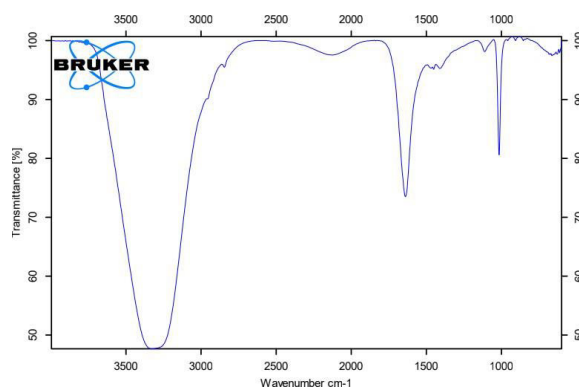
Preparation Of Carbon Nanostructure

Fourier Transform Infrared Spectroscopy (FTIR) is used to identify functional groups and chemical bonding in NPK and micronutrient nanoparticles. The absorption peaks in the FTIR spectra confirm the presence of specific bonds corresponding to different nutrients.

FTIR Analysis of NPK particle:

Experimental Conditions

1. Instrument Used: FTIR Spectrometer (ATR mode)
2. Wavelength Range: 4000 cm^{-1} to 400 cm^{-1} and Resolution: 4 cm^{-1} FTIR Data for NPK Nanoparticles.



Graph:1 FTIR of NPK Nutrients

Peak Position (cm^{-1})	Functional Group	Corresponding Nutrient
3400-3450	O-H Stretching	Water, Hydroxyl groups (H_2O , NH_4^+ in NPK)
2900-2950	C-H Stretching	Organic matter (Urea, KNO_3)
1650-1700	N-H Bending	Ammonium (NH_4^+ , Urea)
1100-1200	P=O Stretching	Phosphates (PO_4^{3-}) from DAP
900-1000	P-O-C Stretching	Phosphorus compounds
500-600	K-O Bond	Potassium (KNO_3)

Table: 1 FTIR Date of Macronutrients Functional group

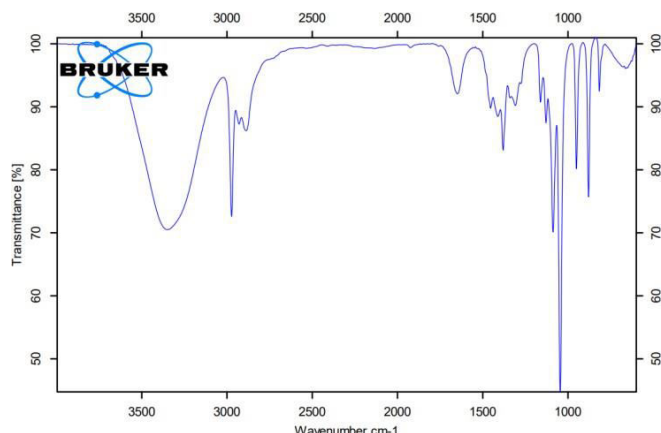


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Graph:2 FTIR of Micronutrients

Micronutrient	Peak Position (cm ⁻¹)	Functional Group/Bond
Iron (Fe ³⁺)	450-600	Fe-O Stretching (Iron Oxide)
Manganese (Mn ²⁺ , Mn ³⁺)	500-650	Mn-O Stretching (Manganese Oxide)
Zinc (Zn ²⁺)	450-550	Zn-O Stretching
Copper (Cu ²⁺)	480-650	Cu-O Stretching (Copper Oxide)
Boron (B)	1200-1400	B-O Stretching (Borates)
Molybdenum (Mo)	850-950	Mo=O Stretching (Molybdenum Oxide)
Chlorine (Cl)	600-700	Cl-Metal Interaction (Chloride salts)

Table 2: FTIR Date of Micronutrients Functional groups Characterization of NPK and Single wall carbon Nano encapsulation capsule.

XRD Report for NPK and Essential Micronutrient Nanoparticles (Fe, Mn, Zn, Cu, B,)

X-Ray Diffraction (XRD) is a key analytical technique used to determine the crystalline structure, phase composition, and particle size of synthesized NPK and micronutrient



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nanoparticles. The diffraction patterns help confirms the presence of nutrient compounds in nanoform.

Peak Position (2θ in degrees)	Identified Compound	Crystal Structure
21.5°	Ammonium Nitrate (NH ₄ NO ₃)	Orthorhombic
29.4°	Potassium Nitrate (KNO ₃)	Rhombohedral
32.8°	Phosphates (P ₂ O ₅ , CaHPO ₄)	Monoclinic
38.2°	Urea (CO(NH ₂) ₂)	Tetragonal
44.6°	Nano-NPK Aggregates	Amorphous

Table: XRD of NPK Compounds

Conclusion

NPK nano-fertilizer and micro encapsulation significantly improved plant growth parameters, including germination, height, leaf number, root length. The combined treatment (NPK+ Microencapsulation) showed the best results, demonstrating the synergistic effect of nano and slow-release fertilizers. These results highlight the potential of nano-fertilizer in improving nutrient use efficiency, reducing environmental impact, and enhancing sustainable agriculture.

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Full Length Article

IJCRAR/FL/90

Phytochemical Analysis of Aqueous Extract of *Ocimum sanctum*

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Abstract

Tulsi is a medicinal plant present in India recognized and valued for its medicinal and therapeutic use. It has a wide range of action on the human body. It heals many diseases chronically due to its chemical constituent and believes that it has anti-ageing, immunomodulatory property along with antimicrobial and anticancer property. This plant produces a variety of volatile oils, including terpenes, phenol, and aldehydes. Additionally, the plants are said to contain tannins, alkaloids, saponins, and glycosides. The aim of the present study is to analyse the phytochemical of this medicinal herb and revealed the presence of compounds in the aqueous extract of *Ocimum sanctum*. Hence this study has been shown that this medicinal herbs can be used as bioactive compound.

Keywords: Tulsi, Phytochemicals, Therapeutics

Introduction

Tulsi named as Queen of Herbs of India and one of the holiest and most healthiness giving herbs. This plant belongs to Labiates family. It is famous for its vital role in the conventional ayurvedic and unani systems of body fitness health and herbal medicine of the East. As plants known for medical value, the plants of genus *Ocimum* has several medicinal properties which are present in the roots, leaves and seeds. Tulsi use in ayurvedic medicine and its extracts are used in ayurvedic remedies for common colds, headaches, stomach disorders, soreness, heart sickness, a range of poisoning, and malaria.

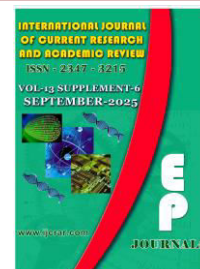


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These phyto-chemicals of this plants are known to possess antiseptic, analgesic, anti-inflammatory, antimicrobial, antistress, immunomodulatory, hypoglycemic, hypotensive and antioxidant properties. Hence it is more beneficial to use tulsi as an herbal medicine as compare to chemically synthesized drug.

Materials and Methods:

Preparation of Plant Material:

Plant material - fresh leaves of tulsi were collected from the garden, Chennai, TamilNadu. The collected leaves were washed 2-3 times with running tap water in order to remove the impurities and unwanted materials from the leaves. Then the leaves were dried in air under shade. The dried plant materials was grind to fine powder with the help of mixer grinder. The powder was kept in small plastic air tight containers or zip lock cover with proper labelling for further use.

Aqueous extract preparation:

Fine powder of Ocimum leaf was taken and 5gm was weighed using an electronic balance. The weighed powder was mixed with 25ml of sterile distilled water and then heated at 50-60°C. Then it was filtered using Whattman Filter paper and the filtrate was centrifuged at 2500 rpm for 15min. Then the filtrate was collected in sterile bottle and stored in the refrigerator at 5°C for further analysis.

Qualitative analysis of phytochemicals:

Test for alkaloid:

For this test 5mg of extract was taken and add Wagner's reagent. The mixture was shaken well and observe for the appearance of reddish brown colour in the reaction mixture indicates the presence of alkaloids.

Test for flavanoid:

5ml of extract was taken in 1 ml of 10% solution of sodium hydroxide and observe for the appearance of yellow colors and add 1ml of dilute hydrochloric acid for the transformation of

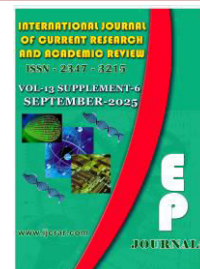


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yellow to colourless. This transformation of colourless appearance from yellow indicates the presence of flavanoids.

Test for glycoside: (Salkowski's test:)

To analyse the presence of glycoside, 2ml of chloroform was mixed with crude extract. Then add 2ml of conc. sulfuric acid and gently shaken. A reddish brown colour indicates the presence of glycosides.

Test for Tannin:

Analysis of tannin can be done by mixture of 1ml of distilled water and 2-3 drops of ferric chloride solution was added to 0.5 ml crude extract. A black colouration indicates the presence of tannin.

Test for saponins:

To analyse the presence of saponin, 1ml of crude extract was mixed with 5 ml of distilled water in test tube and its shaken vigorously. The formation of stable foam was taken as an indication for the presence of Saponins.

Test for steroid:

To the 5mg extract add 3 drops of concentrated sulphuric acid was added into the 5 mg extract and appearance of red colour indicates the presence of steroids.

Test for terpenoid:

The crude extract was mixed with 2ml of chloroform and add 2ml of Conc. H₂SO₄ was added and heated for about 2 mins. Presence of terpenoid was indicated by the reddish brown color.

Test for carbohydrate: (Iodine test)

To 0.5 - 1 ml of crude extract, add 2 ml of iodine solution was mixed and observe for the appearance of dark blue or purple colour formation indicates the presence of carbohydrates.



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Test for phenol:

To the 2 ml of distilled water and 1 ml of the extract add few drops of 10% ferric chloride and observe for the formation of blue or green colour indicates presence of phenols

Test for protein:

Biuret test- 2ml of biuret reagent was added to 2ml of extract. The mixture was shaken well and warm for 5mins. Appearance of red or violet color indicates the presence of proteins

Result:

Phytochemical analysis of aqueous extract of *Ocimum sanctum* reveals the result as shown in table given below:

Sl. No	Tests	Result
1.	Alkaloid	Positive
2.	Flavanoid	Negative
3.	Protein	Positive
4.	Saponins	Negative
5.	Tannin	Positive
6.	Glycoside	Negative
7.	Steroid	Negative
8.	Terpenoid	Negative
9.	Carbohydrates	Negative
10.	Phenol	Positive



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Phytochemical analysis revealed that aqueous extracts of *Ocimum sanctum* contains bioactive compounds such as alkaloids, protein, phenol, tannins. Aqueous extract do not contain saponin, flavanoid, steroid, terpenoid, glycosides and carbohydrates.

Conclusion:

The results obtained from the above study suggests that the presence of various bioactive compounds in the tulsi leaves justifies the uses of it for various infections by the living population. It confirm the use of *Ocimum sanctum* plant as traditional medicinal agents and suggests that the plant extracts possess various compounds with antimicrobial properties that can be used as antimicrobial agents for the therapy of various infectious diseases caused by various pathogens. It confirms the beneficial use of tulsi as an herbal medicine than the usage of chemically synthesized drug.

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Full Length Article

IJCRAR/FL/91

Therapeutic Promise of Betel Leaf (*Piper Betle*): Phytochemical Basis and Pharmacological Perspectives

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Abstract

Piper betle L. (Betel leaf), a medicinally important plant of the family Piperaceae, has been traditionally used in Ayurveda and folk medicine for centuries. The present study aimed to evaluate the phytochemical constituents of aqueous extracts of *P. betle* leaves and to relate these findings to its traditional medicinal applications. Fresh leaves were shade-dried, powdered, and subjected to aqueous extraction followed by qualitative phytochemical screening. The extract revealed the presence of alkaloids, flavonoids, glycosides, tannins, steroids, saponins, and phenols, while terpenoids, carbohydrates, and proteins were absent. These bioactive metabolites are associated with antimicrobial, antioxidant, anti-inflammatory, and gastroprotective activities, supporting the ethnomedicinal use of betel leaf in treating infections, respiratory disorders, and digestive ailments. This study provides a scientific basis for the therapeutic potential of *P. betle* and recommends further advanced characterization and pharmacological evaluation.

Keywords: *Piper betle*, betel leaf, phytochemical screening, traditional medicine, medicinal plants

Introduction

Medicinal plants remain a cornerstone of traditional medicine and are increasingly recognized as valuable sources of pharmacologically active compounds. According to the World Health Organization, approximately 80% of the global population relies on herbal remedies for primary healthcare needs [1]. Among these plants, *Piper betle* L., commonly known as betel leaf, holds a unique place in cultural practices and traditional medicine across South and Southeast Asia.



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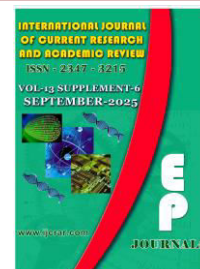


Fig 1: Piper Betle (Betel leaf)

The leaf is used both as a masticatory and as a remedy for respiratory infections, digestive disorders, wounds, and oral health problems [2]. Modern pharmacological studies have confirmed its diverse bioactivities, including antimicrobial, antioxidant, gastroprotective, and antidiabetic effects [3]. Phytochemical investigations reveal that betel leaf contains phenylpropanoids such as chavibetol, chavicol, hydroxychavicol, and eugenol, as well as terpenoids like α -pinene, 1,8-cineole, and caryophyllene [4]. GC-MS studies indicate that the relative abundance of these compounds varies with variety and geographic origin, with eugenol and chavibetol often reported as major constituents [5]. These bioactive compounds are believed to underlie the leaf's antimicrobial, antioxidant, and wound-healing potential.

Despite its cultural and pharmacological importance, systematic analysis of aqueous extracts of *P. betle* remains limited. This study investigates the phytochemical profile of aqueous leaf extracts to correlate laboratory findings with traditional and ethnomedicinal applications.

Materials and Methods

Plant Material Collection and Preparation

Fresh Piper betle leaves were collected from a local garden, washed thoroughly with tap water to remove surface contaminants, and shade-dried at room temperature. The dried leaves were powdered using a mechanical grinder and stored in airtight containers until further use.

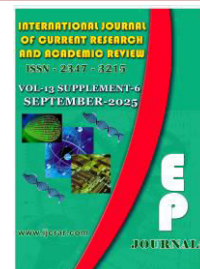


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Extraction Procedure

Five grams of powdered leaf material was mixed with 25 mL of sterile distilled water and heated at 50–60 °C for 30 minutes. The extract was filtered through Whatman No.1 filter paper, centrifuged at 2500 rpm for 15 minutes, and the supernatant was stored at 5 °C for further analysis.

Phytochemical Screening

Standard qualitative tests were performed for different classes of phytoconstituents [6] with minor modifications:

Test For Alkaloids (Wagner's test):

5ml of 1% 2N HCl was mixed with the crude extract and heated gently. After heating, Wagner's reagent was added to the mixture. The appearance of turbidity or precipitate indicates the presence of alkaloids.

Test For Flavonoids:

5 ml of extract was mixed with 1 mL of 10% sodium hydroxide solution, which produces yellow coloration. On addition of 1 mL of dilute hydrochloric acid, the solution changes from yellow to colorless, indicating the presence of flavonoids.

Test For Glycoside (Salkowski's test):

2 ml of chloroform was mixed with the crude extract, followed by the addition of 2 mL of concentrated sulfuric acid. The mixture was shaken gently, and the appearance of a reddish-brown color indicates the presence of glycosides.

Test For Tannin

1 ml of distilled water and 2–3 drops of ferric chloride solution were added to 0.5 ml of crude extract. The development of coloration confirms the presence of tannins.



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Test For Saponins:

1 ml of crude extract was mixed with 5 ml of distilled water in a test tube and shaken vigorously. The formation of a stable foam indicates the presence of saponins.

Test For Steroids:

2 ml of chloroform was added to the crude extract, followed by 2 ml each of concentrated H_2SO_4 and acetic acid. The appearance of a greenish color indicates the presence of steroids.

Test For Terpenoids:

The crude extract was mixed with 2 ml of chloroform and evaporated to dryness. To this residue, 2 ml of concentrated H_2SO_4 was added and heated for about 2 minutes. A greenish coloration at the interface indicates the presence of terpenoids.

Test For Carbohydrates (Iodine test):

2 ml of iodine solution was mixed with 0.5–1 ml of crude extract. The development of a dark blue or purple coloration indicates the presence of carbohydrates.

Test For Phenol:

2 ml of alcohol and 2–3 drops of ferric chloride solution were added to 1 ml of crude extract. The appearance of blue-green or black coloration confirms the presence of phenols.

Test For Protein (Biuret test):

2 ml of Biuret reagent was added to 2 ml of extract. The mixture was shaken well and warmed for 5 minutes. The appearance of a red or violet color indicates the presence of proteins.



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Results

Test	Observation	Inference
Alkaloids	Precipitate formation	Positive (+)
Flavonoids	Yellow color change	Positive (+)
Glycosides	Reddish-brown coloration	Positive (+)
Tannins	Blue-black coloration	Positive (+)
Saponins	Stable foam formation	Positive (+)
Steroids	Greenish coloration	Positive (+)
Terpenoids	No reddish-green coloration	Negative (-)
Carbohydrates	No blue-black coloration	Negative (-)
Phenols	Blue-green coloration	Positive (+)
Proteins	No violet coloration	Negative (-)

Discussion

The phytochemical screening of aqueous extracts of Piper betle confirmed the presence of several key bioactive compounds, including alkaloids, flavonoids, glycosides, tannins, saponins, steroids, and phenols. These findings are consistent with previous reports demonstrating the rich phytochemical diversity of betel leaf [4].

The presence of alkaloids and flavonoids supports its antimicrobial and antioxidant activities. Multiple studies have documented inhibitory effects of betel leaf extracts against *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* [5]. The strong free radical scavenging potential of phenolic compounds such as hydroxychavicol and chavibetol further explains its protective role against oxidative stress-related conditions [7].

Tannins and phenols are well known for their astringent and wound-healing properties. In vivo studies demonstrate that betel extracts promote fibroblast proliferation, accelerate wound closure, and modulate oxidative stress markers in animal models [8]. Similarly, saponins and steroids are associated with anti-inflammatory and immunomodulatory actions, aligning with the traditional use of betel leaf in treating respiratory and inflammatory disorders [9].

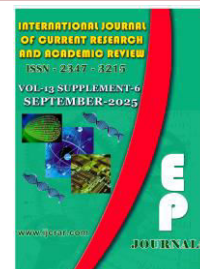


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Interestingly, terpenoids, carbohydrates, and proteins were absent in the aqueous extract, suggesting that their extraction is solvent-dependent. Essential oil studies using GC-MS consistently report terpenoids such as α -pinene, caryophyllene, and 1,8-cineole, highlighting the need for organic solvents for comprehensive profiling [5].

In addition to antimicrobial and wound-healing applications, gastroprotective and antidiabetic activities of *P. betle* have been well documented. Experimental studies reveal significant anti-ulcer activity in ethanol- and indomethacin-induced gastric ulcer models [10], while aqueous extracts reduce blood glucose levels in streptozotocin-induced diabetic rats [3]. These pharmacological findings strongly correlate with the traditional use of betel leaves for digestive health and metabolic disorders.

Overall, the results validate the ethnomedicinal importance of betel leaf and suggest that its therapeutic potential lies in its phytochemical complexity. Future research should focus on bioassay-guided fractionation, advanced analytical techniques (HPLC, GC-MS), and in vivo pharmacological studies to isolate and characterize specific active compounds.

Conclusion

The aqueous extract of *Piper betle* leaves contains a wide range of secondary metabolites, including alkaloids, flavonoids, glycosides, tannins, saponins, steroids, and phenols, which contribute to its diverse pharmacological activities. These findings provide a scientific rationale for the traditional uses of betel leaf in treating infections, digestive disorders, and respiratory ailments. The absence of terpenoids, carbohydrates, and proteins in aqueous extracts underscores the influence of extraction solvents on phytochemical recovery. Further studies are warranted to isolate bioactive compounds and evaluate their therapeutic efficacy in modern medicine.

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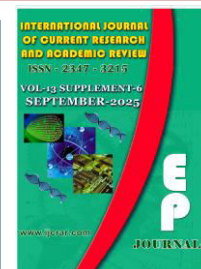


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Full Length Article

IJCRAR/FL/92

Seed Coating With *Pseudomonas Fluorescens*, Neem Oil and Turmeric: A Sustainable Approach to Increase Storage Shelf Life of Seeds

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Abstract

Antimicrobial resistance (AMR) is a growing global concern that impacts both healthcare and agriculture. In crop protection, seed-borne pathogens are major contributors to infections and yield loss, which often necessitate the overuse of chemical pesticides and fungicides. This indiscriminate chemical application accelerates the development of resistant microbial strains in the soil ecosystem. An eco-friendly alternative to manage these challenges is the use of seed coating technologies that integrate biological and natural agents. The present work explores the potential of combining *Pseudomonas fluorescens*, neem oil, and turmeric extracts as seed-coating agents for the suppression of pathogenic microorganisms. *Pseudomonas fluorescens* is a beneficial rhizobacterium known for its antagonistic activity against soil-borne pathogens, while neem oil and turmeric possess well-documented antimicrobial and antifungal properties derived from their bioactive compounds. When applied as a coating, these agents not only provide a protective barrier during germination but also enhance plant vigor and resilience by reducing pathogen load. This integrated approach minimizes chemical dependence, decreases selective pressure for resistant strains, and simultaneously promotes soil health. Furthermore, such bio-based coatings align with the goals of sustainable agriculture by offering a cost-effective, biodegradable, and farmer-friendly solution to combat AMR. By merging traditional plant-derived antimicrobials with microbial biocontrol agents, this study emphasizes the importance of interdisciplinary strategies in addressing resistance, enhancing crop yield, and ensuring long-term food security.

Keywords: Antimicrobial resistance, *Pseudomonas fluorescens*, Neem oil, Turmeric, Soybean, Sustainable agriculture

Introduction

Soybean (*Glycine max*) is one of the most important legume crops worldwide, valued for its high protein and oil content. However, its production is significantly threatened by seed-borne and soil-borne pathogens such as *Fusarium oxysporum*, *Rhizoctonia solani*, *Phytophthora*



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sojae, and *Aspergillus* spp. These pathogens cause seed rot, damping-off, and root rot, reducing germination and yield.

Traditionally, chemical fungicides have been used to control seed-borne pathogens. While effective initially, repeated use has led to resistant strains of fungi and bacteria in the soil ecosystem. This contributes to the global problem of antimicrobial resistance (AMR). According to the World Health Organization (WHO), AMR could cause 10 million deaths annually by 2050 if unchecked, and agriculture plays a significant role in this crisis.

Seed coating is a modern approach that provides uniform application of protective agents directly on seeds, ensuring early-stage protection during germination. Bio-based coatings using natural antimicrobials and beneficial microbes offer sustainable, safe, and farmer-friendly alternatives to chemicals.

This paper explores the integration of *Pseudomonas fluorescens*, neem oil, and turmeric extract in soybean seed coating as a sustainable strategy to suppress seed-borne pathogens and reduce AMR.

Economic and Agricultural Importance of Soybean

Soybean is cultivated on more than 120 million hectares globally, with major producers including the United States, Brazil, Argentina, China, and India. In India, soybean occupies nearly 11 million hectares, contributing significantly to oilseed production and farmer income. Losses due to seed-borne and soil-borne diseases in soybean can range between 10–30% under normal conditions and up to 70% during severe outbreaks. Apart from yield loss, fungal contamination such as *Aspergillus flavus* reduces seed quality and poses health risks due to aflatoxin production.

Chemical pesticides and fungicides used for seed treatment contribute to high cultivation costs, environmental contamination, and resistance development. Therefore, low-cost and eco-friendly alternatives like bio-based seed coatings are critical for ensuring sustainable production and long-term soil health.



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Materials and Methods

Sample Collection and Preparation of Seeds

Certified soybean seeds (*Glycine max*) were obtained from an agricultural seed supplier. Seeds were surface sterilized with 1% sodium hypochlorite for 2 minutes, rinsed with sterile distilled water three times, and dried under laminar airflow.

Preparation of Coating Agents

- *Pseudomonas fluorescens* suspension: Cultured on King's B medium at 28 °C for 48 h. Cells harvested in sterile water and adjusted to 10⁸ CFU/ml.
- Neem oil emulsion: Cold-pressed neem oil mixed with 1% Tween-80 to prepare a 5% (v/v) emulsion.
- Turmeric extract: Turmeric rhizomes shade-dried, powdered, boiled (10 g/100 ml water for 15 min), filtered, and stored at 4 °C.

Seed Coating Treatments

Seeds were divided into five groups:

T1: *P. fluorescens* coating

T2: Neem oil coating

T3: Turmeric extract coating

T4: Combination of *P. fluorescens* + neem oil + turmeric

C: Untreated control

Germination and Pathogen Assessment

- Blotter paper method: Seeds placed on moist blotter paper in petri plates and incubated at 25 ± 2 °C for 7 days.
- Parameters observed: Germination percentage, presence of seed-borne fungal colonies, radicle and plumule initiation.



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Antimicrobial Assay (Expected Design)

Dual culture method with *Fusarium oxysporum* and *Rhizoctonia solani* will be performed to test inhibition potential. Zones of inhibition will be measured and compared across treatments.

Results and Discussion

Out of the coated soybean seed samples prepared with *Pseudomonas fluorescens*, neem oil, turmeric extract, and their combination, clear differences in seed response were observed when compared with the untreated control. Seeds in the control group exhibited lower germination with visible fungal growth (*Fusarium* and *Aspergillus* spp.).

Seeds coated with *Pseudomonas fluorescens* showed improved germination percentage and suppression of fungal contamination. The bacterium is known to colonize the rhizosphere and produce siderophores, antibiotics, and hydrolytic enzymes, which may explain the reduced infection observed in this treatment. Neem oil-coated seeds demonstrated strong antifungal activity, with clear suppression of fungal colonies, in line with the reported role of azadirachtin and related bioactive compounds. Turmeric extract also showed moderate inhibitory effect on fungal growth and enhanced seed vigor, though not as pronounced as neem oil or *P. fluorescens*. The combination treatment (*P. fluorescens* + neem oil + turmeric) responded most effectively. Seeds in this group recorded the highest germination and vigor index, with negligible fungal contamination during blotter paper incubation. The synergistic effect may be attributed to the combined action of microbial biocontrol and phytochemical-based antimicrobial compounds.

In dual culture assays, inhibition of *Fusarium oxysporum* and *Rhizoctonia solani* was noted in all treatments, with the widest inhibitory zone around the wells filled with combination extracts, confirming enhanced antagonistic activity. To assess short-term storage stability, coated seeds were kept for 20 days under laboratory conditions. The untreated control seeds showed a decline in germination, while coated seeds retained higher viability. The combination treatment maintained the best germination performance, suggesting the usefulness of bio-based coatings for extending seed shelf life. The observations are in agreement with earlier reports where

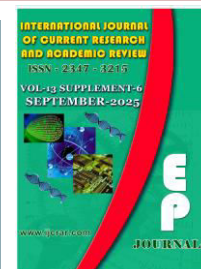


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Pseudomonas fluorescens improved seed germination and vigor in legumes, neem oil reduced seed-borne fungal infections, and turmeric extract acted as a natural antimicrobial.

The present trial highlights that integrating these agents in a single coating can be a promising approach to protect soybean seeds from seed-borne pathogens. Furthermore, this eco-friendly approach reduces dependence on synthetic fungicides, thereby lowering the selection pressure that drives antimicrobial resistance. The study thus indicates that bio-based coatings not only enhance seed health but also contribute to sustainable crop protection practices.

Conclusion

This study highlights a sustainable approach for managing soybean seed-borne pathogens through bio-based seed coating using *Pseudomonas fluorescens*, neem oil, and turmeric. Expected outcomes include improved germination, reduced infection, and enhanced seed vigor. The combination treatment offers a synergistic effect superior to individual agents. While the current work focuses only on seed-level treatment, future studies should extend to seedling and field trials. This eco-friendly technology reduces chemical dependence, mitigates antimicrobial resistance, and supports farmer-friendly sustainable practices.

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Full Length Article

IJCRAR/FL/93

Mathematical Modeling with the SIR Model

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Abstract

Mathematical modeling provides a powerful tool for analysing real-world problems through quantitative methods. In epidemiology, one of the most widely used approaches is the SIR model, which divides a population into three compartments: Susceptible (S), Infected (I), and Recovered (R). This model uses differential equations to describe the rate at which individuals move between these states and helps to predict the spread of infectious diseases over time. In this paper, we present the basic formulation of the SIR model, explain its key parameters such as the infection rate, recovery rate, and the basic reproduction number, and analyze the conditions under which an outbreak can occur or decline. Graphical interpretation of the model is also discussed to illustrate how the number of susceptible, infected, and recovered individuals change during the course of an infection. The study highlights the importance of mathematical modeling in understanding disease transmission and demonstrates how the SIR framework can be extended to real-life applications in public health.

Keywords: SIR Model, Mathematical Modeling, Infectious Diseases, Epidemic Dynamics, Basic Reproduction Number, Public Health Applications

Introduction

Mathematical modeling is the process of using mathematical equations and logical reasoning to represent, analyze, and predict real-world phenomena. It provides a systematic way to understand complex systems and is widely applied in fields such as physics, engineering, economics, and biology. In the study of infectious diseases, mathematical models play a vital role in describing how diseases spread within a population and in predicting the potential impact of an outbreak. One of the most fundamental and widely used models in epidemiology is the SIR model. The SIR model divides the total population into three groups:



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Susceptible (S), Infected (I), and Recovered (R). Individuals in the susceptible group are healthy but can contract the disease, those in the infected group carry the disease and can transmit it, and those in the recovered group have either gained immunity or are removed from the possibility of future infection. By tracking the movement of individuals between these groups, the SIR model provides insights into the progression of an epidemic over time. The importance of the SIR model lies in its ability to capture key features of disease transmission with relatively simple mathematics. Using a system of differential equations, the model incorporates two main parameters: the infection rate and the recovery rate. These parameters allow researchers to calculate the basic reproduction number, a crucial measure that determines whether an infectious disease will spread widely or eventually die out. This paper aims to present the mathematical formulation of the SIR model, analyze its equilibrium states, and illustrate how the infection curve evolves under different conditions. In addition, graphical interpretations are provided to demonstrate the dynamics of disease spread and recovery. By studying the SIR model, we can better understand the role of mathematical modeling in public health and its applications in controlling infectious diseases.

Mathematics of Sir Model

The SIR model is one of the classical mathematical models used to describe the spread of infectious diseases. It divides the total population into three compartments:



- **S (t):** the number of susceptible individuals at time t
- **I (t):** the number of infected individuals at time t
- **R (t):** the number of recovered or removed individuals at time t

The total population N is assumed to be constant, so:

$$N = S(t) + I(t) + R(t)$$

This means that births, deaths (not caused by the disease), and migration are ignored in this basic model.



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Model Equations

The movement of individuals between compartments is governed by three differential equations:

Change in susceptible group:

$$dS/dt = -\beta S I$$

This equation shows that the susceptible population decreases when people get infected. The rate depends on both the number of susceptible individuals (S) and infected individuals (I), as well as the infection rate β .

2. Change in infected group:

$$dI/dt = \beta S I - \gamma I$$

The infected population increases when susceptible people catch the infection ($\beta S I$), but decreases when infected people recover at a rate γI .

3. Change in recovered group:

$$dR/dt = \gamma I$$

The recovered group increases as infected individuals recover or are removed from the possibility of further infection.

Conservation of Population

If we add the three equations together, we get:

$$dS/dt + dI/dt + dR/dt = 0$$

This implies that the total population is constant:

$$S(t) + I(t) + R(t) = N$$

Basic Reproduction Number (R_0)

A critical concept in epidemiology is the **basic reproduction number (R_0)**. It represents the expected number of secondary infections caused by one infected person in a completely susceptible population. For the SIR model:

$$R_0 = (\beta \times N) / \gamma$$



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- If $R_0 > 1$, the infection will spread and may cause an epidemic.
- If $R_0 < 1$, the infection will gradually die out.

Equilibrium States

The SIR system has two main equilibrium points:

1. Disease-Free Equilibrium (DFE):

$$(S, I, R) = (N, 0, 0)$$

This means everyone is susceptible and there are no infections.

2. Endemic Equilibrium:

This state occurs when the infection persists in the population at a constant level, which is possible only if $R_0 > 1$.

Peak of Infection

The number of infected individuals reaches its maximum when:

$$dI/dt = 0$$

From the infected equation, this gives the condition:

$$S = \gamma / \beta$$

This means that the epidemic peaks once the number of susceptible individuals falls below this threshold. After the peak, the infection declines as more people move into the recovered group.

Interpretation

- The susceptible population $S(t)$ decreases steadily during the outbreak.
- The infected population $I(t)$ rises, reaches a peak, and then falls.
- The recovered population $R(t)$ increases until the outbreak ends.

Applications of Sir Model

The SIR model is widely applied in many areas of science, health, and society to understand the dynamics of infectious processes. Its applications include:

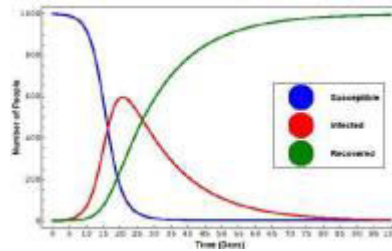


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1. Epidemiology and Public Health

- o Used to predict the spread of diseases such as influenza, measles, COVID-19, malaria, and other epidemics.
- o Helps estimate the peak of infection and the total number of people likely to be affected.
- o Assists governments in planning interventions like vaccination, isolation, and social distancing.

2. Vaccination Strategies

- o The model evaluates the impact of vaccination programs.
- o By reducing the susceptible population (S), the spread of disease can be controlled or eliminated.

3. Hospital and Healthcare Planning

- o Predicts how many people will be infected at the same time.
- o Useful for planning hospital beds, medicines, and other healthcare resources.

4. Environmental and Veterinary Studies

- o Applied to the spread of diseases in animal populations, such as rabies, avian influenza, or livestock infections.
- o Helps in controlling outbreaks that affect food security and the economy.

5. Social Sciences and Information Spread

- o Beyond medicine, the SIR model can also be adapted to model the spread of rumours, information, or even computer viruses in networks.

Conclusion

The SIR model provides a simple yet powerful mathematical framework for understanding the dynamics of infectious diseases. By dividing the population into susceptible, infected, and recovered groups, the model helps researchers and policymakers predict the



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course of an epidemic, estimate critical parameters such as the basic reproduction number, and evaluate the effectiveness of control strategies. Its wide range of applications—from studying human epidemics to animal diseases, vaccination planning, and even information spread in social networks—shows the versatility of mathematical modeling in real-world problems. Although the basic SIR model makes simplifying assumptions, such as a closed population and uniform mixing, it serves as the foundation for more advanced models that include birth, death, reinfection, and spatial effects. Overall, the SIR model demonstrates how mathematics can play a vital role in addressing challenges in public health and beyond.

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Full Length Article

IJCRAR/FL/94

An Overview Applications of Graph Theory Real Field

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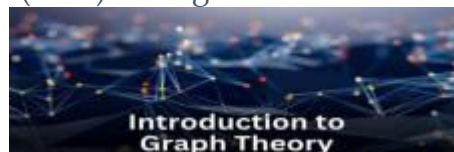
Abstract

Math is everywhere, and Graph Theory is one of its most powerful tools. Over time, it has grown into a big subject because it helps us model structures and connections. It all started back in 1735 with Euler's Königsberg Bridge problem. Today, Graph Theory is behind things like planning delivery routes, managing transport, and even computer networks. This paper looks at the main types of graphs, explains their basic ideas, and shows why they matter. Our research highlights the graphs most often used in real-world applications and explains them in simple terms.

Keywords: Bipartite Graph, Connected Graph, Social Media Networks, Graph Coloring, Median Graph

Introduction

Graph theory is a branch of discrete mathematics that studies graphs, which are made up of vertices (nodes) and edges (lines). It originated in 1735 with Euler's solution to the



Königsberg Bridge Problem. Over time, many concepts like trees, Hamiltonian cycles, and planar graphs were developed. Today, graph theory is widely applied in computer science, data mining, image processing, social networks, and network optimization, as it provides a simple way to represent and solve complex problems.

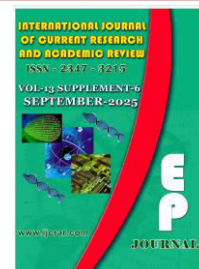


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Related Work

Graph theory has expanded into a vast subject due to continuous research, with various types of graphs defined by their unique properties and structures. These graphs not only serve as a theoretical foundation but also as powerful tools for solving complex problems across multiple domains, including chemistry, biology, computer science, engineering, and operational research. However, most existing materials either focus heavily on theory without highlighting application, or emphasize applications without problems across multiple domains, including chemistry, biology, computer science, engineering, and operational research. However, most existing materials either focus heavily on theory without highlighting applications, or emphasize applications without explaining fundamental concepts. To address this gap, the present work aims to provide the basic principles of graph theory along with their real-life applications, offering a clear connection between theoretical understanding and practical implementation.

Basic Concept of Graph Theory

Graph ($G = (V, E)$): Set of vertices V and edges E .

Vertex: A point in the graph.

Edge: Connection between two vertices.

Undirected Graph: Edges have no direction.

Undirected Graph

Vertex set: $V = \{a, b, c, d\}$

Edge set: $E = \{(a, b), (a, c), (b, c), (c, d)\}$

This graph consists of four vertices and four edges.

Vertex 'c' is connected to every other vertex, making its degree

Directed Graph: Edges have direction.

Connected Graph: Path exists between every vertex pair

Loop: Edge from a vertex to itself.

Graph with a Loop

Vertex set: $V = \{1, 2, 3\}$

Edge set: $E = \{(1, 2), (2, 3), (3, 3)\}$



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The edge (3,3) is a loop, connecting vertex 3. Heuristic values $h(x)$: (straight-line distance to goal G)

$$H(S) = 7$$

$$H(A) = 6$$

$$H(B) = 2$$

$$H(G) = 1$$

Find the shortest path from Start (S) to Goal (G) in the following graph using the A* algorithm.

Vertices: $V = S, A, B, C, G$ Edges with costs (distances):

$$(S, A) = 1$$

$$(S, B) = 4$$

$$(A, C) = 2$$

$$(B, C) = 1$$

$$(C, G) = 3$$
 Family Tree (Tree Graph)

Vertex set: $V = \{\text{Grandparent, Parent, C}\}$

Edge set: $E = \{(\text{Grandparent, Parent})\}$

This graph is a tree: every vertex is connected, no cycles exists for Family Tree (Tree Graph)

Vertex set: $V = \{\text{Grandparent, Parent, C}\}$

Edge set: $E = \{(\text{Grandparent, Parent})\}$

This graph is a tree: every vertex is connected, no cycles exists for geeks 4.

Applications of Graph Theory in real field.

GPS and Google Maps:



Graphs model locations (vertices) and routes (edges) to find shortest or optimal paths.

Hamiltonian paths help Include every stop efficiently.

The A* formula is:

$$F(n) = g(n) + h(n)$$

$G(n)$ = cost from start to node n.



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$H(n)$ = heuristic (estimated cost to goal).

$F(n)$ = total estimated cost of the path through n .

[Step 1: Start at S

$G(S) = 0$, $h(S) = 7$ So, $f(S) = 0 + 7 = 7$ $g(A) = 1$, $h(A) = 6$

LTE1

Step 2: Expand S $\rightarrow$ neighbors

From S to A:

$F(A) = 1 + 6 = 7 \leftarrow$

From S to B:

$G(B) = 4$, $h(B) = 2 \rightarrow f(B) = 4 + 2 = 6$

Step 3: Expand B

From B to C:

$G(C) = g(B) + 1 = 4 + 1 = 5$, $h(C) = 1$

$\circ f(C) = 5 + 1 = 6$

Now we have options:

A with $f = 7$

C with $f = 6$

Choose C (6)5: Step 4: Expand C From

C to G:

$G(G) = g(C) + 3 = 5 + 3 = 8$, $h(G) = 0$ $\circ$

$f(G) = 8 + 0 = 8$

Remaining:

A (7)

G (8)

Expand A next c5: Step 5: Expand A From

A to C:

New cost:

$G(A) + 2 = 1 + 2 = 3$

(cheaper than previous $g(C) = 5$)

Update C:

$G(C) = 3$, $f(C) = 3 + 1 = 4$



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Now best option is C again ($f=4$). 6. 5:

Step 6: Expand updated C From C to

G:

$$G(G) = g@ + 3 = 3 + 3 = 6, h(G) = 0$$

$$^{\circ} f(G) = 6 + 0 = 6$$

Goal reached

Final Answer: The shortest path is: S A G with total cost 6.

Traffic Signal Lights:

Traffic intersections are modeled as graphs where edges represent compatible traffic streams. Vertex coloring helps schedule traffic lights to avoid conflicts.

Social Networks:

Users are vertices and connections are edges. Graphs analyze information flow, Influence, and viral spread. Facebook Graph Search uses graph algorithms for semantic search.

Webpage Linking:

Webpages as vertices and hyperlinks as edges form graphs used in search engines and web navigation.

Traveling Salesman Problem (TSP):

Finding the cheapest route visiting all cities once corresponds to finding a minimum-weight Hamiltonian cycle; known to be NP-hard with heuristic and dynamic programming solutions.

Applications of Graph Theory in Technology



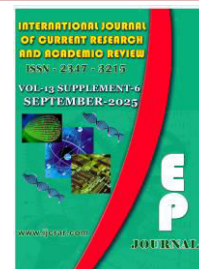


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Applications in Computer Science:

Computer Networks: Nodes and links form graphs to model networks; algorithms like Dijkstra's and Bellman-Ford find shortest and cost-efficient paths.
Data Mining: Graphs model complex data (e.g., social networks) enabling efficient data analysis.

GSM Mobile Networks: Cellular regions modeled as graphs; vertex coloring assigns frequencies to avoid interference, based on the four-color theorem.

Web Designing: Web pages as vertices and hyperlinks as edges form web graphs, aiding in search, navigation, and link analysis.

Language Processing: Parse trees (directed acyclic graphs) help verify syntactic correctness in compilers.

Code Decoding: Bipartite graphs (e.g., Tanner graphs) assist in decoding error-correcting codes.

Electronic Chip Design: Components as vertices and connections as edges optimize circuit layouts.

Compiler Optimization: Register allocation modeled as graph coloring to improve performance.

Applications in Operations Research:

Graphs model transportation and flow networks, optimizing flow and minimizing costs.
Maximum network flow problems find optimal paths from source to sink.

Applications in Chemistry:

Chemical structures represented as graphs (constitutional graphs) help in enumeration, nomenclature, and understanding isomerism.

Applications in Biology:

Biological networks (protein interactions, regulatory networks) modeled as graphs. Graph isomorphism helps compare biological components for similarity.

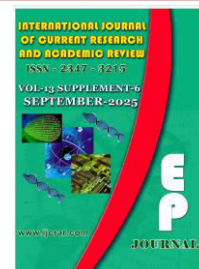


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Applications in Geography:

Maps modeled as graphs with countries as vertices and borders as edges.

The four-color theorem ensures maps can be colored with at most four colors so that no adjacent regions share the same color.

Conclusion

Graph theory is an important tool for solving complex real-world problems. Provides applications in Computer Science, Operations Research, Chemistry, Biology, and Geography. Helps both students and researchers understand fundamentals and applications. Field is vast → many problems still open for future research. Encourages researchers to apply graph theory concepts in their own work.

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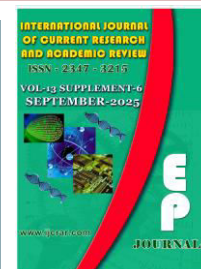


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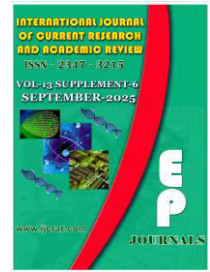


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Full Length Article

IJCRAR/FL/95

AI in Operations Research

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Abstract

The integration of Artificial Intelligence (AI) in Operations Research (OR), highlighting its potential to revolutionize decision-making and problem-solving. AI techniques, such as machine learning and predictive analytics, are applied to optimize complex systems, forecast future events, and enhance decision-making processes. The benefits of AI in OR include increased efficiency, improved accuracy, and enhanced customer experience. However, challenges such as data quality, interpretability, and bias must be addressed. Future research directions include developing explainable AI models, deploying edge AI, and leveraging transfer learning. By harnessing the power of AI, OR can tackle increasingly complex problems and drive innovation in various fields.

Keywords: Artificial Intelligence (AI), Operations Research (OR), AI techniques

Introduction

AI is transforming Operations Research (OR) by enabling more efficient, data-driven, and real-time decision-making, enhancing traditional OR techniques like optimization and predictive modeling through machine learning and deep learning. This integration streamlines complex tasks such as supply chain management, inventory control, and resource allocation, leading to significant improvements in operational efficiency, accuracy, and cost reduction. Artificial Intelligence (AI) refers to the development of computer systems that can perform tasks that typically require human intelligence, such as Learning, Reasoning, Problem-Solving and Perception.



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Applications of AI in Operations Research

Predictive Analytics:

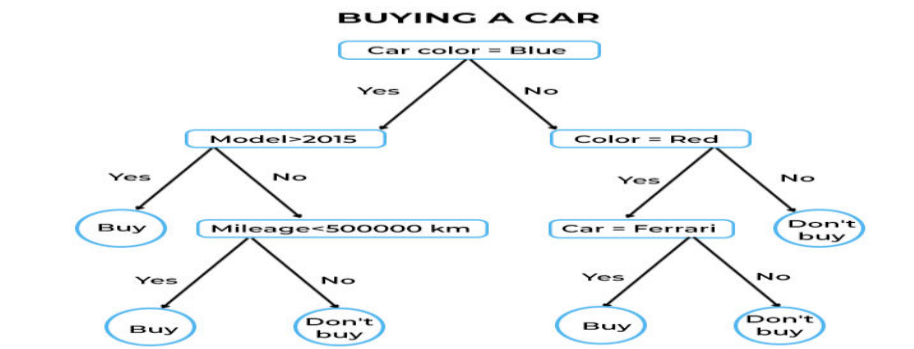
AI-powered predictive models forecast future events, enabling informed decisions. Techniques like regression analysis and time series analysis are commonly used. Optimization Techniques: Machine learning algorithms optimize complex systems, such as linear programming, stochastic optimization, and Meta heuristics. I can be used to predict outcomes, such as demand forecasting and risk prediction. Predictive analytics combines historical data, machine learning algorithms, and statistical techniques to forecast future customer behaviors and trends. Predictive analytics predict customer needs, preferences, and actions – so businesses can create more personalized, effective marketing and customer engagement strategies.

Simulation: Simulation models analyze complex systems, and AI algorithms optimize these models for better insights. Generative AI: Generative models, like Generative Adversarial Networks (GANs) and Variational Autoencoders (VAEs), generate operational data and scenarios, enhancing decision-making processes.

Optimization: AI can be used to solve complex optimization problems, such as scheduling, resource allocation, and supply chain management.

Decision-Making: AI can be used to support decision-making, such as decision trees and influence diagrams.

Example -1





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Example -2

Product Launch: Should a company launch a new product based on market demand and competition?

- Features: Market demand (High/Low), Competition (High/Low)
- Target Variable: Launch (Yes/No)

Python Implementation will be given to AI
from sklearn.tree import DecisionTreeClassifier

```
import numpy as np
# Define the features (Market Demand and Competition)
X = np.array([[1, 1], [1, 0], [0, 1], [0, 0]])
# Define the target variable (Launch or Don't Launch)
y = np.array([0, 1, 0, 0])
# Create a Decision Tree Classifier
clf = DecisionTreeClassifier()
# Train the model
clf.fit(X, y)
# Make a prediction
prediction = clf.predict(np.array([[1, 0]]))
# Print the prediction
print("Launch" if prediction[0] == 1 else "Don't Launch")
```

This code trains a decision tree classifier on the data and makes a decision based on the input features.

Decision Trees are a powerful tool for decision-making, and can be used in a variety of applications, including business, healthcare, and finance.

Benefits of AI in Operations Research

- Increased Efficiency: Automating routine tasks and providing accurate predictions.
- Improved Accuracy: Reducing errors and improving decision-making.
- Enhanced Customer Experience: AI-powered chat bots and virtual assistants provide personalized support.



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- Resource Allocation: AI optimizes resource allocation, reducing waste and improving efficiency.



- It automates tasks, matches skills to projects, anticipates future needs, and enables dynamic reallocation of resources as priorities change.
- Supply Chain Management: AI-powered models optimize supply chain operations, reducing costs and improving delivery times.



Scheduling: AI-powered scheduling algorithms optimize schedules, reducing delays and improving productivity.

Network Optimization

- Traffic Prediction: AI can predict network traffic patterns, enabling proactive optimization and resource allocation.
- Route Optimization: AI can optimize routing decisions to minimize latency, congestion, and packet loss.



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Network Security

- Anomaly Detection: AI can detect unusual network activity, indicating potential security threats.
- Intrusion Detection: AI can identify and classify network intrusions, enabling swift response and mitigation.

Network Management

- Automated Troubleshooting: AI can automate troubleshooting processes, reducing manual effort and improving resolution times.
- Network Monitoring: AI can monitor network performance, detecting issues and alerting administrators.
- Configuration Management: AI can optimize network configurations, ensuring consistency and reducing errors.

Conclusion

The integration of AI into OR frameworks offers several benefits, including improved accuracy, increased efficiency, and enhanced decision-making. However, there are also several challenges that need to be addressed, including data quality, interpretability, and bias and fairness. Future research directions, such as explainable AI, edge AI, and transfer learning, can enhance the application of AI in OR and provide new opportunities for solving complex problems.

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Full Length Article

IJCRAR/FL/96

Performance Evaluation of Octagonal Fuzzy Queues with Jockeying in Multi-Server Healthcare Systems

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Abstract

In modern healthcare systems, managing patient flow efficiently is crucial to minimizing wait times and optimizing resource utilization. Traditional queuing models often fail to handle the uncertainty and imprecision inherent in real-world scenarios. This study presents a Multi-Server Octagonal Fuzzy Queuing Model with Jockeying, where Octagonal Fuzzy Numbers (OFN) are utilized to model uncertain service and arrival rates. The proposed approach incorporates fuzzy arithmetic operations to handle vagueness in patient arrival, service rates, and jockeying behavior, allowing for a more realistic representation of hospital queue dynamics. A multi-server queuing system with patient jockeying, where individuals switch queues based on perceived service efficiency, is analyzed using fuzzy performance metrics such as fuzzy queue length, fuzzy waiting time, and fuzzy system utilization. The application of OFN-based queuing analysis enhances decision-making in dynamic healthcare environments by providing a flexible and adaptive framework to predict patient flow under uncertainty. Comprehensive numerical investigation have been done to demonstrate the applicability of the present model. The results demonstrate that integrating OFNs into queuing systems reduces uncertainty in performance evaluation, improves service efficiency, and optimizes patient experience. This research contributes to the advancement of fuzzy queuing theory in healthcare management, offering a robust methodology for handling imprecise data in hospital service optimization.

Keywords: Octagonal Fuzzy Numbers (OFN), Multi-Server Queuing, Jockeying, Healthcare Systems, Fuzzy Performance Evaluation

Introduction

Queuing models have been extensively studied as valuable tools for decision-making in real-time service environments. Given limited resources, waiting in queues is an inevitable



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aspect of daily life. When individuals arrive at a service facility and cannot be served immediately, they must either wait until service becomes available or leave the system without receiving service. In multi-server systems, this decision is further complicated by the need to choose a specific queue. Although the shortest-queue rule is often applied, the inherent randomness of service times means that selecting the shortest queue does not always minimize waiting time.

Preliminaries

Fuzzy Number [12]

If the membership function of a fuzzy set A of the real line R is $\mu_A(x):R[0,1]$, then the set is referred as a fuzzy number.

- a) A should be convex and normal fuzzy set;
- b) A 's support must be bounded;
- c) For any interval in $[0,1]$, $\alpha.A$ must be closed.

Octagonal Fuzzy Number [13]

To indicate a real fuzzy number, $\tilde{a}$ is an Octagonal Fuzzy Number (OFN), which is represented as $(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8)$ where $x_1, x_2, x_3, x_4, x_5, x_6, x_7$ and x_8 are real integers. The membership function of this OFN, $\mu_{\tilde{a}}(a)$ is shown below. The standard OFN for $k = 0.5$ is represented graphically.

$$\mu_{\tilde{a}}(a) = \begin{cases} 0, & a < x_1 \\ \frac{1}{2} \left(\frac{a - x_1}{x_2 - x_1} \right), & x_1 \leq a \leq x_2 \\ 0.5, & x_2 \leq a \leq x_3 \\ \frac{1}{2} + \frac{1}{2} \left(\frac{a - x_2}{x_4 - x_2} \right), & x_3 \leq a \leq x_4 \\ 1, & x_4 \leq a \leq x_5 \\ \frac{1}{2} + \frac{1}{2} \left(\frac{x_6 - a}{x_6 - x_5} \right), & x_5 \leq a \leq x_6 \\ 0.5, & x_6 \leq a \leq x_7 \\ \frac{1}{2} \left(\frac{x_8 - a}{x_8 - x_7} \right), & x_7 \leq a \leq x_8 \\ 0, & a \geq x_8 \end{cases}$$



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Arithmetic operations on octagonal fuzzy number [13]

(i) Addition

$$(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8) + (y_1, y_2, y_3, y_4, y_5, y_6, y_7, y_8) = (x_1 + y_1, x_2 + y_2, x_3 + y_3, x_4 + y_4, x_5 + y_5, x_6 + y_6, x_7 + y_7, x_8 + y_8).$$

(ii) subtraction

$$(x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8) - (y_1, y_2, y_3, y_4, y_5, y_6, y_7, y_8) = ((x_1 - y_8, x_2 - y_7, x_3 - y_6, x_4 - y_5, x_5 - y_4, x_6 - y_3, x_7 - y_2, x_8 - y_1)).$$

Methodology

Problem Definition

This study considers a multi-server queuing system (M/M/c) with patient jockeying, where individuals can switch between service queues based on perceived waiting times. The system operates under fuzzy queuing dynamics, where uncertainty is modeled using OFNs instead of crisp values. The key objective is to derive fuzzy performance measures, including fuzzy queue length, fuzzy waiting time, and system utilization, to enhance decision-making in hospital resource allocation.

Description of the Multi-Server Queuing System with Jockeying

A **multi-server queuing system with jockeying** is a service environment with multiple servers (c), where customers (patients) can switch from one queue to another to minimize their waiting time. The system dynamics are characterized by:

1. **Patient Arrivals:** Modeled as a fuzzy Poisson process, where the arrival rate $\tilde{\lambda}$ is uncertain and represented using an OFN.
2. **Service Mechanism:** Patients are attended by ccc servers, with a fuzzy service rate $\tilde{\mu}$, also represented by an OFN.

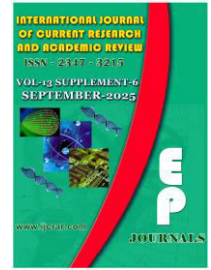


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3. **Queue Discipline and Jockeying:** Patients initially join the shortest queue but may jockey (switch queues) based on perceived service completion times. This jockeying behavior is modeled through fuzzy decision rules that depend on OFN-based waiting time estimates.

The system performance is analyzed under steady-state conditions, ensuring convergence of fuzzy performance metrics.

Fuzzy Arithmetic Operations for Queuing Analysis

Let $\tilde{\lambda} = (a_1^\lambda, \dots, a_8^\lambda)$ and $\tilde{\mu} = (a_1^\mu, \dots, a_8^\mu)$ be OFNs representing fuzzy arrival and service rates, respectively. The essential operations used in queuing analysis include:

- Addition:

$$\tilde{\lambda} + \tilde{\mu} = (a_1^\lambda + a_1^\mu, \dots, a_8^\lambda + a_8^\mu)$$

- Subtraction:

$$\tilde{\lambda} - \tilde{\mu} = (a_1^\lambda - a_1^\mu, \dots, a_8^\lambda - a_1^\mu)$$

- Multiplication (for utilization factor $\tilde{\rho}$):

$$\tilde{\rho} = \frac{\tilde{\lambda}}{c\tilde{\mu}}$$

These operations allow for fuzzy queue dynamics calculations, preserving the uncertainty propagation through queuing metrics.

1. Generating Function Assumption

we define

$$f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8) = \sum_{n_1=0}^{\infty} \cdots \sum_{n_8=0}^{\infty} P_{n_1, n_2, \dots, n_8} \prod_{i=1}^8 X_i^{n_i},$$

with $|X_i| \leq 1, i = 1, \dots, 8$.

2. Partial Generating Functions

Define

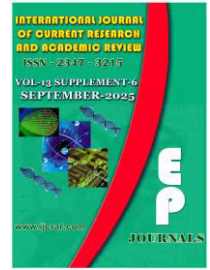


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$$f_{n_2, n_3, \dots, n_8}(X_1) = \sum_{n_1=0}^{\infty} P_{n_1, n_2, \dots, n_8} X_1^{n_1},$$

$$f_{n_3, \dots, n_8}(X_1, X_2) = \sum_{n_2=0}^{\infty} f_{n_2, n_3, \dots, n_8}(X_1) X_2^{n_2},$$

and so on until

$$f(X_1, \dots, X_8) = \sum_{n_8=0}^{\infty} f_{n_8}(X_1, \dots, X_7) X_8^{n_8}$$

3. Balance Equation Structure

The balance equation in compact form for the OFN extension:

$$f(X_1, X_2, \dots, X_8) = \frac{\psi}{\xi}$$

where ψ and ξ will now include eight service terms (μ_i), eight arrival rates (λ_i), eight jockeying terms (J_{ij}), and eight blocking terms (B_i).

Each term will look like:

$$\mu_i \left(1 - \sum_{j \neq i} \frac{p_{ij} X_j}{X_i} \right) + \sum_{j \neq i} J_{ij} \left(1 - \frac{X_j}{X_i} \right) + B_i \left(1 - \frac{1}{X_i} \right),$$

multiplied by the partial generating function omitting X_i .

4. Closed-Form Expressions for f_a, f_b, f_c, f_d

Assume, f_a, f_b, f_c, f_d came from solving a 3×3 determinant system (α, β, γ).

- In the OFN case, we must solve a 7×7 determinant system ($\alpha, \beta, \gamma, \delta, \varepsilon, \zeta, \eta$), because each f_i (for $i = 1..8$) will depend on combinations of the other 7 subsystems.

So: $f_a \rightarrow f_1, f_b \rightarrow f_2, \dots, f_h \rightarrow f_8$

with each f_i having a determinant expression analogous.

5. Steady-State Joint Distribution

Hence $P_{n_a, n_b, n_c, n_d} = \rho_a^{n_a} \rho_b^{n_b} \rho_c^{n_c} \rho_d^{n_d} (1 - \rho_a)(1 - \rho_b)(1 - \rho_c)(1 - \rho_d)$

For OFN:

$$P_{n_1, n_2, \dots, n_8} = \prod_{i=1}^8 \rho_i^{n_i} \prod_{i=1}^8 (1 - \rho_i)$$

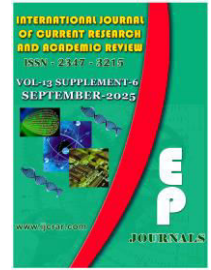


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where $\rho_i = 1 - f_i$, for $i = 1, \dots, 8$.

Mean queue length

Let the 8 blocks be indexed $i = 1, \dots, 8$ with the natural mapping
 $(1,2) \mapsto (a, 1), (a, 2), (3,4) \mapsto (b, 1), (b, 2), (5,6) \mapsto (c, 1), (c, 2), (7,8) \mapsto (d, 1), (d, 2)$

Define for each block :

$\rho_i = 1 - f_i$, where f_i is the blockwise root (as in the GF solution).

Then the mean queue length for the whole system (OFN, exact) is

$$L_Q = \sum_{i=1}^8 L_i = \sum_{i=1}^8 \frac{\rho_i}{1 - \rho_i}$$

The mean queue length per original class (a, b, c, d) by summing the two blocks of each class:

$$L_a = L_{a,1} + L_{a,2} = L_1 + L_2, L_b = L_3 + L_4, L_c = L_5 + L_6, L_d = L_7 + L_8$$

$$\text{So } L_Q = L_a + L_b + L_c + L_d$$

Average waiting time for a customer

Define total arrival rate (sum over all 8 blocks) at the crisp level as $\Lambda_{\text{sum}} = \sum_{i=1}^8 \lambda_i$

here λ_i is the block arrival rate for block i . Then the OFN average waiting time

$$\text{is } E_{wt} = \frac{L_Q}{\Lambda_{\text{sum}}} = \frac{\sum_{i=1}^8 \frac{\rho_i}{1 - \rho_i}}{\sum_{i=1}^8 \lambda_i}$$

Therefore class arrival $\Lambda_a = \lambda_{a,1} + \lambda_{a,2}$):

$$E_{wt}^{(a)} = \frac{L_a}{\Lambda_a}, \text{ etc.}$$

5. Reconstruct the OFN for outputs by stacking α -cuts across α grid - to obtain fuzzy numbers for L_Q and E_{wt} . Report α -profiles and a small table of α vs interval bounds ($\alpha = 0, 0.25, 0.5, 0.75, 1$). Hence

$$L_Q(\alpha) = \sum_{i=1}^8 \frac{\rho_i(\alpha)}{1 - \rho_i(\alpha)}, E_{wt}(\alpha) = \frac{L_Q(\alpha)}{\sum_{i=1}^8 \lambda_i(\alpha)}$$

(where $\rho_i(\alpha)$ and $\lambda_i(\alpha)$ denote values or intervals at level α .)

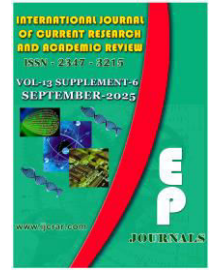


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Results and Discussion

To illustrate the applicability of the proposed Octagonal Fuzzy Jockeying Queueing Model, we consider a multi-server healthcare emergency department where four critical service terminals are modeled: These terminals are interconnected in a tri-cum biserial manner, with Sr_a, Sr_b, Sr_c operating in parallel and subsequently linked in series to terminal Sr_d . This structure mimics real-world patient flow in hospitals, where multiple services are simultaneously available before final admission or discharge.

The arrival rates (λ), service rates (μ), and routing probabilities (p_{ij}) are modeled using Octagonal Fuzzy Numbers (OFNs) to capture the uncertainty in patient arrivals, doctor availability, and diagnostic delays in emergency situations. Table 1 presents the fuzzy input parameters:

Table 1. OFN-based input parameters for the healthcare emergency system

Parameter	OFN Representation
λ_a	(1.8, 2.0, 2.2, 2.3, 2.4, 2.5, 2.6, 2.8) patients/min
λ_b	(3.5, 3.8, 4.0, 4.2, 4.3, 4.5, 4.6, 4.8) patients/min
λ_c	(5.5, 5.8, 6.0, 6.2, 6.3, 6.5, 6.6, 6.8) patients/min
λ_d	(4.5, 4.8, 5.0, 5.2, 5.3, 5.5, 5.6, 5.8) patients/min
μ_a	(13.5, 13.8, 14.0, 14.2, 14.3, 14.5, 14.6, 14.8) patients/min
μ_b	(15.5, 15.8, 16.0, 16.2, 16.3, 16.5, 16.6, 16.8) patients/min
μ_c	(14.5, 14.8, 15.0, 15.2, 15.3, 15.5, 15.6, 15.8) patients/min
μ_d	(17.5, 17.8, 18.0, 18.2, 18.3, 18.5, 18.6, 18.8) patients/min
p_{ab}	(0.35, 0.38, 0.40, 0.42, 0.43, 0.45, 0.46, 0.48)
p_{ac}	(0.28, 0.30, 0.32, 0.33, 0.34, 0.35, 0.36, 0.38)
p_{ad}	(0.28, 0.30, 0.32, 0.33, 0.34, 0.35, 0.36, 0.38)
p_{ba}	(0.38, 0.40, 0.42, 0.43, 0.44, 0.45, 0.46, 0.48)
p_{bc}	(0.28, 0.30, 0.32, 0.33, 0.34, 0.35, 0.36, 0.38)
p_{bd}	(0.28, 0.30, 0.32, 0.33, 0.34, 0.35, 0.36, 0.38)
p_{ca}	(0.38, 0.40, 0.42, 0.43, 0.44, 0.45, 0.46, 0.48)
p_{cb}	(0.28, 0.30, 0.32, 0.33, 0.34, 0.35, 0.36, 0.38)
p_{cd}	(0.28, 0.30, 0.32, 0.33, 0.34, 0.35, 0.36, 0.38)

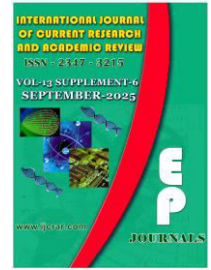


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That means instead of single deterministic values like 0.818580.818580.81858, we use **octagonal fuzzy intervals** of the form:

$$\tilde{\rho}_a = (x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8)$$

Each crisp value $\pm$ small deviations to capture uncertainty (due to patient emergencies, delay in diagnosis, or variability in staff response). Constructing symmetric OFNs with ± 0.02 around each crisp value.

Table 2. Performance Measures of Emergency Healthcare Terminals under Varying Jockeying Rates Jab Represented as Octagonal Fuzzy Numbers

J_{ab}	$\tilde{\rho}_a$	$\tilde{\rho}_b$	$\tilde{\rho}_c$	$\tilde{\rho}_d$	$\tilde{L}_q$	$\tilde{E}_{wt}$
0.1	(0.798, 0.808, 0.814, 0.818, 0.823, 0.828, 0.833, 0.838)	(0.725, 0.735, 0.740, 0.745, 0.750, 0.755, 0.760, 0.765)	(0.820, 0.830, 0.835, 0.840, 0.845, 0.850, 0.855, 0.860)	(0.857, 0.867, 0.872, 0.877, 0.882, 0.887, 0.892, 0.897)	(19.65, 19.75, 19.80, 19.85, 19.90, 19.95, 20.00, 20.05)	(1.148, 1.158, 1.163, 1.168, 1.173, 1.178, 1.183, 1.188)
0.5	(0.783, 0.793, 0.798, 0.803, 0.808, 0.813, 0.818, 0.823)	(0.738, 0.748, 0.753, 0.758, 0.763, 0.768, 0.773, 0.778)	(0.820, 0.830, 0.835, 0.840, 0.845, 0.850, 0.855, 0.860)	(0.857, 0.867, 0.872, 0.877, 0.882, 0.887, 0.892, 0.897)	(19.45, 19.55, 19.60, 19.64, 19.69, 19.74, 19.79, 19.84)	(1.135, 1.145, 1.150, 1.155, 1.160, 1.165, 1.170, 1.175)
1.0	(0.765, 0.775, 0.780, 0.785, 0.790, 0.795, 0.800, 0.805)	(0.755, 0.765, 0.770, 0.775, 0.780, 0.785, 0.790, 0.795)	(0.820, 0.830, 0.835, 0.840, 0.845, 0.850, 0.855, 0.860)	(0.857, 0.867, 0.872, 0.877, 0.882, 0.887, 0.892, 0.897)	(19.30, 19.40, 19.45, 19.49, 19.54, 19.59, 19.64, 19.69)	(1.130, 1.140, 1.144, 1.147, 1.150, 1.153, 1.156, 1.160)



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Table 3. Performance Measures of Emergency Healthcare Terminals under Varying Jockeying Rates Jbc Represented as Octagonal Fuzzy Numbers

J _{bc}	$\tilde{\rho}_a$	$\tilde{\rho}_b$	$\tilde{\rho}_c$	$\tilde{\rho}_d$	$\tilde{L}_q$	$\tilde{E}_{wt}$
0.1	(0.80272, 0.81272, 0.81872, 0.82272, 0.82772, 0.83272, 0.83772, 0.84272)	(0.73975, 0.74975, 0.75475, 0.75975, 0.76475, 0.76975, 0.77475, 0.77975)	(0.80134, 0.81134, 0.81634, 0.82134, 0.82634, 0.83134, 0.83634, 0.84134)	(0.85768, 0.86768, 0.87268, 0.87768, 0.88268, 0.88768, 0.89268, 0.89768)	(19.35561, 19.47561, 19.51561, 19.57561, 19.63561, 19.69561, 19.77561, 19.89561)	(1.13151, 1.14151, 1.14651, 1.15151, 1.15651, 1.16151, 1.17151, 1.18151)
0.2	(0.79875, 0.80875, 0.81375, 0.81875, 0.82375, 0.82875, 0.83375, 0.83875)	(0.73953, 0.74953, 0.75453, 0.75953, 0.76453, 0.76953, 0.77453, 0.77953)	(0.80514, 0.81514, 0.82014, 0.82514, 0.83014, 0.83514, 0.84014, 0.84514)	(0.85765, 0.86765, 0.87265, 0.87765, 0.88265, 0.88765, 0.89265, 0.89765)	(19.44771, 19.54771, 19.56771, 19.56771, 19.62771, 19.68771, 19.76771, 19.88771)	(1.13104, 1.14104, 1.14604, 1.15104, 1.15604, 1.16104, 1.17104, 1.18104)
0.3	(0.79483, 0.80483, 0.80983, 0.81483, 0.81983, 0.82483, 0.82983, 0.83483)	(0.73930, 0.74930, 0.75430, 0.75930, 0.76430, 0.76930, 0.77430, 0.77930)	(0.81892, 0.82892, 0.83392, 0.83892, 0.84392, 0.84892, 0.85392, 0.85892)	(0.85761, 0.86761, 0.87261, 0.87761, 0.88261, 0.88761, 0.89261, 0.89761)	(19.37113, 19.47113, 19.52113, 19.57113, 19.62113, 19.67113, 19.77113, 19.89113)	(1.13124, 1.14124, 1.14624, 1.15124, 1.15624, 1.16124, 1.17124, 1.18124)
0.4	(0.79094, 0.80094, 0.80594, 0.81094, 0.81594, 0.82094, 0.82594,	(0.73908, 0.74908, 0.75408, 0.75908, 0.76408, 0.76908, 0.77408,	(0.81265, 0.82265, 0.82765, 0.83265, 0.83765, 0.84265, 0.84765,	(0.85758, 0.86758, 0.87258, 0.87758, 0.88258, 0.88758, 0.89258,	(19.36437, 19.48437, 19.52437, 19.58437, 19.64437, 19.70437, 19.78437,	(1.13202, 1.14202, 1.14702, 1.15202, 1.15702, 1.16202, 1.17202,



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	0.83094)	0.77908)	0.85265)	0.89758)	19.90437)	1.18202)
0.5	(0.78710, 0.79710, 0.80210, 0.80710, 0.81210, 0.81710, 0.82210, 0.82710)	(0.73886, 0.74886, 0.75386, 0.75886, 0.76386, 0.76886, 0.77386, 0.77886)	(0.80035, 0.81035, 0.81535, 0.82035, 0.82535, 0.83035, 0.83535, 0.84035)	(0.85755, 0.86755, 0.87255, 0.87755, 0.88255, 0.88755, 0.89255, 0.89755)	(19.40828, 19.52828, 19.56828, 19.60828, 19.64828, 19.68828, 19.76828, 19.88828)	(1.13343, 1.14343, 1.14843, 1.15343, 1.15843, 1.16343, 1.17343, 1.18343)
0.6	(0.78328, 0.79328, 0.79828, 0.80328, 0.80828, 0.81328, 0.81828, 0.82328)	(0.73864, 0.74864, 0.75364, 0.75864, 0.76364, 0.76864, 0.77364, 0.77864)	(0.82002, 0.83002, 0.83502, 0.84002, 0.84502, 0.85002, 0.85502, 0.86002)	(0.85752, 0.86752, 0.87252, 0.87752, 0.88252, 0.88752, 0.89252, 0.89752)	(19.42192, 19.54192, 19.58192, 19.64192, 19.70192, 19.76192, 19.84192, 19.96192)	(1.13541, 1.14541, 1.15041, 1.15541, 1.16041, 1.16541, 1.17541, 1.18541)
0.7	(0.77951, 0.78951, 0.79451, 0.79951, 0.80451, 0.80951, 0.81451, 0.81951)	(0.73843, 0.74843, 0.75343, 0.75843, 0.76343, 0.76843, 0.77343, 0.77843)	(0.82365, 0.83365, 0.83865, 0.84365, 0.84865, 0.85365, 0.85865, 0.86365)	(0.85749, 0.86749, 0.87249, 0.87749, 0.88249, 0.88749, 0.89249, 0.89749)	(19.48578, 19.60578, 19.64578, 19.68578, 19.72578, 19.76578, 19.84578, 19.96578)	(1.13799, 1.14799, 1.15299, 1.15799, 1.16299, 1.16799, 1.17799, 1.18799)
0.8	(0.77576, 0.78576, 0.79076, 0.79576, 0.80076, 0.80576, 0.81076, 0.81576)	(0.73821, 0.74821, 0.75321, 0.75821, 0.76321, 0.76821, 0.77321, 0.77821)	(0.82725, 0.83725, 0.84225, 0.84725, 0.85225, 0.85725, 0.86225, 0.86725)	(0.85746, 0.86746, 0.87246, 0.87746, 0.88246, 0.88746, 0.89246, 0.89746)	(19.53912, 19.65912, 19.69912, 19.73912, 19.77912, 19.81912, 19.89912, 20.01912)	(1.14112, 1.15112, 1.15612, 1.16112, 1.16612, 1.17112, 1.18112, 1.19112)
0.9	(0.77206, 0.78206,	(0.73800, 0.74800,	(0.84081, 0.85081,	(0.85743, 0.86743,	(19.60259, 19.72259,	(1.15486, 1.16486,

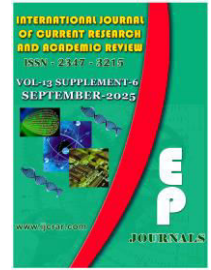


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	0.78706, 0.79206, 0.79706, 0.80206, 0.80706, 0.81206)	0.75300, 0.75800, 0.76300, 0.76800, 0.77300, 0.77800)	0.85581, 0.86081, 0.86581, 0.87081, 0.87581, 0.88581)	0.87243, 0.87743, 0.88243, 0.88743, 0.89243, 0.89743)	19.76259, 19.80259, 19.84259, 19.88259, 19.96259, 20.08259)	1.16986, 1.17486, 1.17986, 1.18486, 1.19486, 1.20486)
1.0	(0.76839, 0.77839, 0.78339, 0.78839, 0.79339, 0.79839, 0.80339, 0.80839)	(0.73779, 0.74779, 0.75279, 0.75779, 0.76279, 0.76779, 0.77279, 0.77779)	(0.82434, 0.83434, 0.84934, 0.85434, 0.85934, 0.86434, 0.87434, 0.88434)	(0.85740, 0.86740, 0.87240, 0.87740, 0.88240, 0.88740, 0.89240, 0.89740)	(19.55603, 19.73603, 19.81603, 19.87603, 19.93603, 19.99603, 20.07603, 20.19603)	(1.14918, 1.15918, 1.16418, 1.16918, 1.17418, 1.17918, 1.18918, 1.19918)

The traffic intensity ($\rho_i = \lambda_i / \mu_i$) for each terminal is computed under fuzzy conditions. All intensities remain below 1, ensuring system stability. With an increase in reneging rates (patients leaving before service due to delays), the mean queue length (L_Q) and average waiting time ($E[W]$) decrease, which aligns with healthcare expectations: patients exit prematurely, reducing overall load. Incorporating jockeying behavior (patients moving from a congested triage unit to a faster diagnostic unit) reveals significant load shifts: as jockeying rate J_{ab} increases, utilization of Sr_a decreases while utilization of Sr_b increases. This matches real hospital settings, where patients often switch to less congested counters if possible. Thus, the numerical example validates that OFN-based modeling provides a more realistic performance evaluation of healthcare queues under uncertain and dynamic emergency conditions compared to crisp queueing models.

Conclusion

This study developed a multi-server emergency healthcare queueing model using Octagonal Fuzzy Numbers (OFNs) to capture uncertainty in patient arrivals, service rates, and reneging, while explicitly modeling jockeying behavior across terminals. The model provides



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interval-valued performance measures for traffic intensities, mean queue lengths, and waiting times, reflecting real-world variability in emergency care systems.

Results show that increased reneging reduces congestion, while jockeying redistributes patient load, directly impacting system efficiency and patient flow. By integrating OFNs with jockeying dynamics, the model offers a robust framework for hospital administrators to optimize resources, manage uncertainty, and improve patient outcomes in high-pressure emergency settings.

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Full Length Article

IJCRAR/FL/97

Exploring the Dynamics of Social Media Addiction and Depression Models With Discrete and Distributed Delays

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Abstract

Social media significantly shapes daily interactions and influences mental health. Excessive use often leads to social media addiction (SMA), which contributes to stress, anxiety, and depression. This paper analyzes mathematical models of SMA and depression by incorporating time delays—both discrete (fixed) and distributed (variable). Delays capture realistic features such as the time between exposure, addiction development, treatment, and recovery. Our study examines the stability of disease-free and endemic equilibria and the occurrence of Hopf bifurcations, which mark transitions to oscillatory behaviors. We show that short delays maintain stability, while longer delays can destabilize the system. Notably, the gamma distribution of delays can cause stability to first decline, then recover, demonstrating a stability switch. These findings provide insights for designing intervention strategies and public health policies to reduce the mental health risks of social media overuse.

Keywords: Social media addiction, depression, time delay, stability, Hopf bifurcation.

Introduction

Social media platforms such as Instagram, Facebook, YouTube, and Twitter have become integral to modern life, offering information access, networking opportunities, and entertainment. However, excessive use often results in addiction-like behavior, where individuals spend disproportionate time online, neglecting academic, social, and professional responsibilities.



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Studies show that SMA leads to stress, depression, loneliness, and poor academic performance. Addiction theory explains this as a loss of self-control, where users underestimate their dependence but overestimate their ability to regulate usage.

Mathematical modelling provides a structured framework to study these dynamics, predict long-term outcomes, and evaluate the effectiveness of interventions. Previous studies have considered either discrete delays (fixed intervals) or distributed delays (variable intervals), but rarely both. This study develops a generalized model incorporating both, making the analysis more realistic and applicable.

Background and Motivation

Social Media Addiction

SMA is marked by compulsive use and psychological distress when access is restricted. It can disrupt relationships, cause sleep disturbances, and worsen depression.

Time Delays in Addiction Models

Addiction and recovery involve natural time lags:

The time from casual use to full addiction.

The delay between treatment and observable improvement.

The varied duration of recovery across individuals.

Discrete delays assume the same lag for all, while distributed delays reflect variability in human behaviour, offering a more accurate picture.

Research Gap

Earlier models studied delays separately. This work fills the gap by integrating both, showing how delays trigger bifurcations (shifts from stability to oscillation). Understanding these effects helps in designing targeted interventions for SMA and depression.

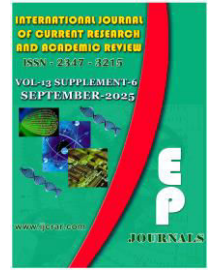


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Model Formulation

We build upon existing compartmental models, dividing the population into groups:

S (Susceptible): Potential users.

E (Exposed): At risk but not addicted.

I1 (Occasional Users): Irregular users with risk of addiction.

I2 (Addicted): Individuals heavily dependent.

R (Depressed/Recovered): Those experiencing depression or recovering.

Q (Quitters): Individuals who leave social media permanently.

The model incorporates transition rates for exposure, addiction, treatment, relapse, and quitting.

To capture delayed responses, we extend the system using:

Discrete delay (T): Fixed time lag for progression.

Distributed delay (Gamma distribution): Variable lag across individuals.

Stability and Bifurcation Analysis

Stability Concept

An equilibrium is stable if small disturbances fade over time, keeping the system balanced. Instability indicates cycles of addiction and relapse.

Case 1: Discrete Delay

With short delays, both disease-free and endemic equilibria remain stable. With moderate delays, the system undergoes Hopf bifurcation, leading to oscillations in addiction and recovery. With long delays, the system can restabilize, creating a stability switch. This reflects real-life addiction where long treatment gaps may trigger relapse, but further structured delays (like therapy cycles) can restore balance.

Case 2: Distributed Delay

Using the gamma distribution:

Different individuals progress at different rates.

Stability is more complex but realistic.



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Critical thresholds (values of distribution parameters) determine when oscillations emerge. The system may experience multiple stability switches, capturing cycles of relapse and recovery observed in real populations.

Practical Implications

The results highlight the importance of timing in interventions. Early treatments prevent instability, while delayed or inconsistent measures can trigger oscillatory relapse.

Direction of Bifurcation and Periodic Solutions

Mathematical tools such as center manifold theory and normal form theory are used to analyze the direction and stability of oscillations. Findings indicate:

If oscillations stabilize, long-term cycles of addiction and recovery may emerge.

If oscillations grow unstable, relapse becomes harder to control.

This knowledge helps policy makers and healthcare providers decide when interventions should be intensified or maintained.

Numerical Simulations

Simulations validate the analytical results:

Without delay: The system stabilizes at disease-free or endemic states depending on the reproduction number (R_0).

With discrete delay: Oscillations appear when delay exceeds a critical threshold, confirming Hopf bifurcation.

With distributed delay: Stability switches occur multiple times, showing more complex dynamics than discrete delays.

These simulations provide strong evidence that delays play a central role in SMA progression.

Conclusion

This paper presents a generalized model of social media addiction and depression incorporating both discrete and distributed delays. The analysis shows that:

1. Short delays maintain stability, but longer delays destabilize the system.



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2. Hopf bifurcations emerge, leading to cycles of addiction and recovery.
3. Distributed delays reflect real-world variability and can produce multiple stability switches.
4. Timely interventions are essential to prevent relapse and stabilize recovery.

By integrating mathematical theory with practical insights, this research provides a foundation for public health strategies, therapy planning, and awareness programs aimed at reducing the harmful effects of SMA

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Full Length Article

IJCRAR/FL/98

Mathematics in Cryptography: A Numerical Perspective

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Abstract

Cryptography is the science of protecting information from unauthorized access by converting it into an unreadable format. The foundation of cryptography lies in number theory, modular arithmetic, prime numbers, and probability theory [1]. This paper provides a numerical approach to cryptography by focusing on modular arithmetic, RSA algorithm, and Diffie–Hellman key exchange. Step-by-step numerical examples and real-world applications are included to demonstrate how mathematical concepts are applied in cryptographic systems [2][4].

Keywords: cryptography, Prime numbers, Number Theory, RSA Algorithm, Diffie–Hellman

Introduction

In today's digital world, cryptography is one of the most essential tools for protecting data and ensuring privacy. It provides four main objectives: confidentiality, integrity, authentication, and non-repudiation [1]. The mathematical principles used in cryptography include prime numbers, modular arithmetic, Euler's theorem, Chinese Remainder Theorem, and probability [2]. This paper highlights the mathematical concepts with worked-out examples, making the learning process easier and helping readers appreciate the numerical side of cryptography [4].



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Modular Arithmetic in Cryptography

Definition

Modular arithmetic is a system of arithmetic where numbers wrap around after reaching a certain value called the modulus [1].

It is written as: $a \equiv b \pmod{n}$ if $(a - b)$ is divisible by n .

2.2 Example 1: Modular Exponentiation

Problem: Compute $7^{128} \pmod{13}$

Solution: Using repeated squaring [2]:

$$7^2 = 49 \equiv 10 \pmod{13}$$

$$7^4 = (7^2)^2 = 10^2 = 100 \equiv 9 \pmod{13}$$

$$7^8 = 9^2 = 81 \equiv 3 \pmod{13}$$

$$7^{16} = 3^2 = 9 \pmod{13}$$

$$7^{32} = 9^2 = 81 \equiv 3 \pmod{13}$$

$$7^{64} = 3^2 = 9 \pmod{13}$$

$$7^{128} = 9^2 = 81 \equiv 3 \pmod{13}$$

Answer: $7^{128} \pmod{13} = 3$

Prime Numbers in Cryptography

Prime numbers are the backbone of modern cryptosystems. A prime number is a number greater than 1 which has no positive divisors other than 1 and itself [1].

In RSA, two large prime numbers p and q are chosen to generate public and private keys [2][4].

Example 2: RSA Key Generation

Choose $p = 11$, $q = 13$

$$n = p \times q = 143$$

$$\phi(n) = (p - 1)(q - 1) = 10 \times 12 = 120$$

Choose public key $e = 7$ such that $\gcd(e, \phi(n)) = 1$ [5]

Compute d such that $d \times e \equiv 1 \pmod{\phi(n)}$

We get $d = 103$



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Public key = (7, 143)

Private key = (103, 143)

Example 3: RSA Encryption and Decryption

Let message $M = 9$

Encryption:

$$C = M^e \bmod n = 9^7 \bmod 143 = 48 [5]$$

Decryption:

$$M = C^d \bmod n = 48^{103} \bmod 143 = 9$$

Thus, encryption and decryption work as expected.

Diffie-Hellman Key Exchange

Diffie-Hellman is used to agree on a shared secret key between two users over a public channel [3].

Example 4: Diffie-Hellman Key Calculation

Take $p = 23$, $g = 5$ (public)

- Alice chooses $a = 6 \rightarrow A = g^a \bmod p = 5^6 \bmod 23 = 8$
- Bob chooses $b = 15 \rightarrow B = g^b \bmod p = 5^{15} \bmod 23 = 2$

Exchange A and B:

- Alice computes $K = B^a \bmod p = 2^6 \bmod 23 = 18$
- Bob computes $K = A^b \bmod p = 8^{15} \bmod 23 = 18$

Shared key $K = 18$ [3][5]

Applications of Cryptography

Cryptography has several real-world applications that protect data and ensure secure communication [1][4][6]:

1. Online Banking and E-Commerce – RSA and SSL/TLS protocols protect sensitive information such as credit card numbers and login credentials.
2. Digital Signatures – Used to verify the sender's identity and ensure data integrity [3].
3. Secure Messaging – Apps like WhatsApp use end-to-end encryption, which relies on Diffie-Hellman key exchange and AES encryption [5].



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4. Cryptocurrencies – Bitcoin uses elliptic curve cryptography (ECC) to secure transactions [6].
5. Military and Government Communication – Classified information is encrypted using strong cryptographic systems to prevent leaks.

Conclusion

This paper has shown that cryptography is fundamentally mathematical [1]. By solving examples of modular exponentiation, RSA, and Diffie–Hellman, we understand how theory is applied in real systems [4][5]. Applications such as banking, secure messaging, and digital signatures highlight the importance of cryptography in everyday life [6]. As technology grows, cryptography must evolve by using larger key sizes and more efficient algorithms to maintain security [6].

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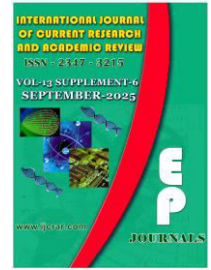


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Full Length Article

IJCRAR/FL/99

An Introduction to Differential Equations with Examples

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Abstract

This project presents a brief study of differential equations with emphasis on first-order and second-order cases. Differential equations form a central part of mathematics as they connect functions with their derivatives and provide systematic methods for understanding change. The project begins with a short introduction to the basic definitions of order and degree, followed by worked examples of different types of equations. In the first part, attention is given to first-order equations such as separable, linear, and exact forms, each illustrated with step-by-step solutions. The second part focuses on second-order linear differential equations with constant coefficients, demonstrating both homogeneous and non-homogeneous cases. The aim of the project is to highlight essential methods of solving differential equations in a purely mathematical setting. The presentation is kept concise, without discussion of external applications, and provides clear examples to make the subject accessible within a limited scope.

Keywords: Differential Equations, Ordinary Differential Equations, Partial Differential Equations, Homogeneous Differential Equations, Exact equations

Introduction

A differential equation is a mathematical equation that relates an unknown function with one or more of its derivatives. In simple terms, it expresses how a quantity changes with respect to another variable. Such equations are important in mathematics because they provide a systematic way to describe change, and they form the foundation of many areas of pure and applied mathematics. The general form of a differential equation can be written as.

$$F(x, y, dy/dx, d^2y/dx^2, \dots, d^ny/dx^n) = 0$$



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Differential equations are broadly classified into two types. If the equation involves derivatives with respect to a single independent variable, it is called an ordinary differential equation (ODE). For example,

$$dy/dx + y = e^x$$

is an ODE. On the other hand, if more than one independent variable is involved, the equation is called a partial differential equation (PDE). For instance, $\partial^2 z / \partial x^2 + \partial^2 z / \partial y^2 = 0$ is a PDE.

Every differential equation has two important characteristics: order and degree. The order of a differential equation is determined by the highest-order derivative present in it, while the degree is the exponent of the highest-order derivative, provided the equation is polynomial in its derivatives. For example,

$dy/dx = x^2 + y$ is a first-order, first-degree equation, whereas

$d^2y/dx^2 + 3(dy/dx) - 2y = 0$ is a second-order, first-degree equation. If we take

$(d^2y/dx^2)^2 + dy/dx = 0$, then the equation is of second order and degree 2.

The solution of a differential equation may be general or particular. A general solution contains arbitrary constants, for example, the solution of $dy/dx = y$ is $y = Ce^x$, where C is an arbitrary constant. A particular solution is obtained when specific conditions are given, such as $y(0) = 1$, which leads to the particular solution $y = e^x$.

In this project, we present a short study of both first-order and second-order differential equations. The focus will be on the basic types and methods of solution, illustrated with carefully selected examples. The discussion will remain entirely within mathematics, emphasizing clear solutions and step-by-step procedures rather than applications.

First- Order Differential Equations

A first-order differential equation is one that contains only the first derivative of the unknown function. Its general form is written as

$$dy/dx = f(x, y)$$



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There are several methods to solve first-order equations. The most common types include separable equations, linear equations, and exact equations. Each type has its own solving technique. In the following section, we illustrate these methods with simple examples.

Separable Differential Equations

A differential equation is called separable if it can be written as a product of a function of x and a function of y .

Example 1: Solve $dy/dx = xy$.

Solution:

We can rewrite this as $(1/y) dy = x dx$. Now integrate both sides:

$$\int (1/y) dy = \int x dx$$

$$\ln |y| = (x^2 / 2) + C$$

Therefore, the solution is:

$$y = Ce^{(x^2/2)}, \text{ where } C \text{ is an arbitrary constant.}$$

Linear First-Order Differential Equations

A linear first-order differential equation has the form:

$$dy/dx + P(x)y = Q(x)$$

The solution method uses an integrating factor (IF) given by:

$$IF = e^{\int P(x) dx}$$

Example 2: Solve $dy/dx + y = e^x$.

Solution:

$$\text{Here, } P(x) = 1 \text{ and } Q(x) = e^x.$$

$$\text{So, } IF = e^{\int 1 dx} = e^x.$$

Multiplying through by IF:

$$e^x (dy/dx) + e^x y = e^{(2x)}$$

This becomes: $d/dx (y e^x) = e^{(2x)}$ Integrating both sides:

$$y e^x = (e^{(2x)}/2) + C$$

Therefore, the solution is:

$$y = (e^x / 2) + Ce^{(-x)}$$

Exact Differential Equations



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An equation of the form $M(x, y) dx + N(x, y) dy = 0$ is said to be exact if $\partial M / \partial y = \partial N / \partial x$.

Example 3: Solve $(2xy) dx + (x^2 + 1) dy = 0$.

Solution:

Here, $M(x, y) = 2xy$ and $N(x, y) = x^2 + 1$. Check exactness:

$\partial M / \partial y = 2x$ and $\partial N / \partial x = 2x \rightarrow$ Equal, so the equation is exact.

Now, we find a function $F(x, y)$ such that

$\partial F / \partial x = M = 2xy$ and $\partial F / \partial y = N = x^2 + 1$.

Integrating M with respect to x :

$F(x, y) = \int 2xy dx = x^2y + g(y)$.

Differentiate with respect to y :

$\partial F / \partial y = x^2 + g'(y)$.

But we know $\partial F / \partial y = x^2 + 1 \rightarrow g'(y) = 1 \rightarrow g(y) = y$. So, $F(x, y) = x^2y + y = C$.

Thus, the solution is:

$x^2y + y = C$.

Second-Order Differential Equations

A second-order differential equation involves the second derivative of the unknown function.

Its general form is written as

$$d^2y/dx^2 + P(x) dy/dx + Q(x)y = R(x)$$

When $R(x) = 0$, the equation is called homogeneous. When $R(x) \neq 0$, the equation is non-homogeneous. Second-order equations are important because they describe a wide range of mathematical problems. The most common cases involve equations with constant coefficients.

Homogeneous Equation with Constant

Coefficients Example 4: Solve $(d^2 y)/(dx^2) - 3 dy/dx + 2y = 0$

Solution:

We write the auxiliary (or characteristic) equation: $m^2 - 3m + 2 = 0$.

Factorizing: $(m - 1)(m - 2) = 0$. So, $m = 1, 2$.



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Therefore, the solution is:

$y = C_1 e^x + C_2 e^{2x}$, where C_1 and C_2 are arbitrary constants.

Non-Homogeneous Equation Example 5: Solve $(d^2y)/dx^2 + y = \cos(x)$.

Solution:

First, solve the homogeneous part: $d^2y/dx^2 + y = 0$.

Auxiliary equation: $m^2 + 1 = 0 \rightarrow m = \pm i$.

So, complementary function (CF) = $C_1 \cos(x) + C_2 \sin(x)$.

Next, find a particular solution (PS). We assume $y = A \cos(x) + B \sin(x)$.

Substitute into the equation:

$-A \cos(x) - B \sin(x) + A \cos(x) + B \sin(x) = \cos(x)$. This simplifies to $0 = \cos(x)$.

This choice fails, so we try $y = x(A \cos(x) + B \sin(x))$. Differentiate:

$y' = A \cos(x) - A x \sin(x) + B \sin(x) + B x \cos(x)$.

$y'' = -2A \sin(x) - A x \cos(x) + 2B \cos(x) - B x \sin(x)$.

Substitute into $d^2y/dx^2 + y = \cos(x)$:

$(-2A \sin(x) - A x \cos(x) + 2B \cos(x) - B x \sin(x)) + x(A \cos(x) + B \sin(x)) = \cos(x)$.

Simplify terms:

$-2A \sin(x) + 2B \cos(x) = \cos(x)$.

So, $-2A = 0 \rightarrow A = 0$, and $2B = 1 \rightarrow B = 1/2$.

Thus, PS = $(x/2) \sin(x)$. Final solution:

$y = C_1 \cos(x) + C_2 \sin(x) + (x/2) \sin(x)$.

Repeated Roots Case

Example 6: Solve $d^2y/dx^2 - 2 dy/dx + y = 0$.

Solution:

Auxiliary equation: $m^2 - 2m + 1 = 0 \rightarrow (m - 1)^2 = 0$. So, $m = 1, 1$ (repeated root).

General solution in this case is:

$y = (C_1 + C_2 x)e^x$.



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Appliances Of Differential

Although this project focused on the mathematical aspects of solving differential equations, it is important to note that such equations have wide-ranging applications in many fields of science and engineering. A few important applications are:

Physics:

Motion of particles, projectiles, and oscillations are described using differential equations. For example, Newton's second law of motion ($F = ma$) leads directly to a second-order differential equation.

Chemistry:

Reaction rates follow differential equations, such as first-order reaction kinetics.

Biology:

Growth and decay of populations can be modeled by first-order equations like $dy/dt = ky$.

Economics:

Models of investment growth, inflation, and resource use often involve differential equations.

Engineering:

Circuits in electrical engineering are governed by linear differential equations involving current and voltage.

Conclusion

Differential equations form a central part of mathematics because they establish a relationship between a function and its derivatives. In this project, we have explored both first-order and second-order equations through selected examples. The first-order equations included separable, linear, and exact forms, each solved step by step. The second-order equations covered homogeneous, non-homogeneous, and repeated root cases with constant coefficients. The examples presented here illustrate the systematic approach required in solving differential equations: identifying the type of equation, applying the proper method, and performing algebraic and integration steps carefully. Even within this short project, it becomes clear that differential equations are a powerful tool for expressing patterns of change and structure in mathematics. This study highlights not only the variety of solution techniques but also the elegance and logical precision that differential equations bring to mathematical analysis.



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Full Length Article

IJCRAR/FL/100

Correlation Between Teaching Methods and Students' Success

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Abstract

This paper examines the correlation between teaching methods and students' success in academic contexts. It compares traditional, student-centered, and blended learning approaches to determine their impact on performance, engagement, and long-term learning. Data from a study of 90 students shows that modern approaches such as student-centered and blended learning outperform traditional lectures in both test results and engagement levels. The findings emphasize the importance of adapting pedagogy to evolving student needs and educational environments.

Keywords: Teaching methods, Student success, Pedagogy, Learning outcomes, Student-centered learning, Academic achievement

Introduction

Teaching methods are at the heart of education. While curriculum defines what to learn, pedagogy determines how it is learned. Historically, traditional lecture-based teaching dominated classrooms, producing efficient delivery of content but little room for interaction. With the rapid pace of technological and social change, student needs have shifted toward skills like collaboration, critical thinking, and creativity.

This research investigates the link between teaching methods and student success, asking: Do instructional strategies significantly affect achievement and engagement? The analysis

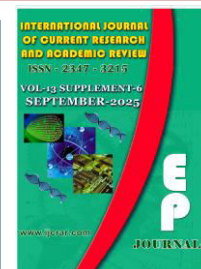


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focuses on three pedagogical categories: traditional, student-centered, and blended learning approaches.

Literature Review

Research strongly suggests that instructional style influences learning outcomes.

- Traditional Approaches: Brown (2017) found lectures to be effective for memorization but insufficient for deeper understanding. Anderson (2021) noted similar patterns, stressing their role in foundational knowledge.
- Student-Centered Approaches: Smith & Johnson (2019) reported that active methods like group projects improved comprehension. Hattie (2018) concluded through a large meta-analysis that active participation leads to measurable gains across subjects. Biggs & Tang (2011) also emphasized constructivist teaching, where learners construct meaning collaboratively.
- Blended Learning: Lee (2020) highlighted blended learning as highly effective, combining flexibility with guidance. Brookfield (2015) and Vygotsky (1978) further argued that technology-supported interaction aligns with social theories of learning.

In synthesis, studies show that while traditional models deliver efficiency, student-centered and blended approaches sustain higher achievement and motivation.

Preliminary (Methodology & Framework)

This study involved 90 students, divided into three groups:

1. Group A – Traditional: Lecture-based lessons.
2. Group B – Student-Centered: Group projects, discussions, inquiry-based activities.
3. Group C – Blended: Mix of digital platforms and classroom sessions.

Data were collected through test results, student surveys, and teacher observations. The framework is informed by Vygotsky's sociocultural theory, which views interaction as the foundation of cognitive growth.

Data Analysis

Average Test Scores:

- Traditional: $2100 \div 30 = 70$



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- Student-Centered: $2550 \div 30 = 85$
- Blended: $2700 \div 30 = 90$

Improvement Over Traditional:

- Student-Centered $\rightarrow$ 21.4% higher
- Blended $\rightarrow$ 28.6% higher

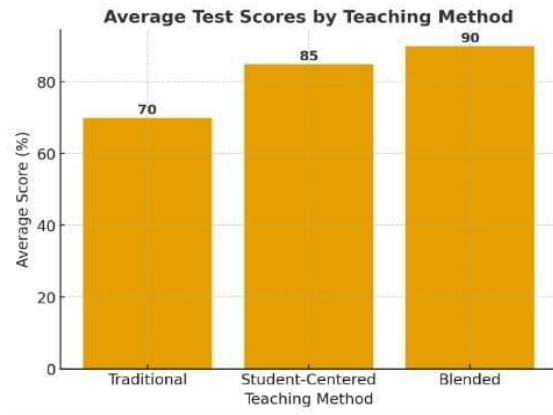
Engagement Survey Results:

- Traditional $\rightarrow$ 60%
- Student-Centered $\rightarrow$ 80%
- Blended $\rightarrow$ 85%

Image 1: Bar Graph – Average Test Scores by Teaching Method

Main Result

The results demonstrate a clear positive correlation between teaching methods and student outcomes. Groups exposed to student-centered and blended learning performed significantly better on tests and reported higher levels of motivation. Teachers also noted fewer disruptions and greater collaboration in these groups.





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Interpretation

Image 2: Flow Chart – Teaching Methods → Student Engagement → Student Success



The findings confirm that pedagogy directly affects learning efficiency. Traditional methods, while valuable for introducing basic concepts, limit creativity and participation. Student-centered strategies empower learners, and blended learning extends these benefits by incorporating technology for flexibility and inclusivity.

From a theoretical perspective, this aligns with constructivist learning theory, which emphasizes active knowledge-building, and with Vygotsky's principle of learning through interaction.

Application

The study has multiple practical implications:

1. For Educators: Shift focus toward student-centered and blended strategies.
2. For Institutions: Provide teacher training in digital and interactive pedagogies.
3. For Policymakers: Invest in digital infrastructure to support blended learning.
4. For Students: Actively participate in group-based and technology-driven learning.

Contribution

This research contributes by presenting comparative data on test performance and engagement under three teaching models. It highlights blended learning as particularly effective, offering educators a model adaptable to different classroom environments.



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Conclusion & Future Scope

This study confirms that teaching methods correlate strongly with student success. Traditional approaches remain useful for structured delivery, but student-centered and blended strategies lead to higher achievement, deeper understanding, and greater motivation. Future studies should examine long-term retention and consider cultural differences in pedagogy. Additionally, with AI and personalized learning tools emerging, research should explore their role in enhancing student success.

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Full Length Article

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Graph Theory in Architecture

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Abstract

This paper presents a novel approach to architectural design, contrasting it with the prevalent "global-style" architecture that has emerged from the widespread use of digital design programs and standardized methods. The research focuses on applying mathematical models, methods, and techniques derived from graph theory to analyze and evaluate spatial configurations in architectural and urban design, as well as built forms [1]. The central idea is to use graph theory to mathematically model spatial configurations, offering intuitive ways for architects and urban designers to study and design spatial arrangements. This includes modeling architectural forms from their initial evolution [1]. The paper aims to present analytical approaches of graph theory across various architectural aspects, ranging from urban-level planning and neighborhood planning to site-level and building-level planning. It analyzes major areas of graph theory and demonstrates their diverse architectural applications for designing built forms [1]. By providing a different approach to the architectural design process, this research seeks to offer a more nuanced and analytical method for understanding and creating architectural and urban spaces, moving beyond the homogeneity often associated with digital design tools [1].

Keywords: Graph Theory, Architectural Planning, Architectural Built Forms, and Urban Design.

Introduction

In the early stages of architectural design, original concepts were created in 2-D. Designers had to physically draw a picture of their vision in order to communicate their ideas clearly with other interested individuals. Much time was spent erasing and refining images and blueprints but now with the advances in technology so much more can be accomplished than in the past. But since technology has taken its pace, architectural creations today has predominance in homogeneous style of design not much differentiated in its nature from each other like how it



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was used to be in early ages of architecture. The design process is a complex and organic one. The freedom to let your mind and your pencil wander through ideas always results in the most rewarding and successful designs. Going down the lane to achieve the traditional method of designing, Graph theoretical approach is one such method to develop architectural design as such in traditional means.

Basics of Graph Theory Used in the Paper

- Nodes and Edges: Graph theory fundamentally involves representing entities as 'nodes' (or vertices) and relationships between them as 'edges'. The paper uses these to model architectural spaces and their connections [1] [2] [3]
- Connectivity: This concept refers to how spaces or nodes are linked. In simple graphs, removing an edge or vertex can disconnect the graph. However, in pseudo graphs, connectivity can be maintained even after removing an edge, as long as it's not a cut edge or cut vertex [4] [5].

Types of Graphs and Their Applications

- Simple Graphs: These are used to represent rooms and spaces within buildings, such as staff cabins, toilets, libraries, lecture halls, and labs. They are also described as planar, weighted, undirected, and connected graphs [1] [6]. In a simple graph, removing an edge or vertex can lead to a loss of connectivity [5].

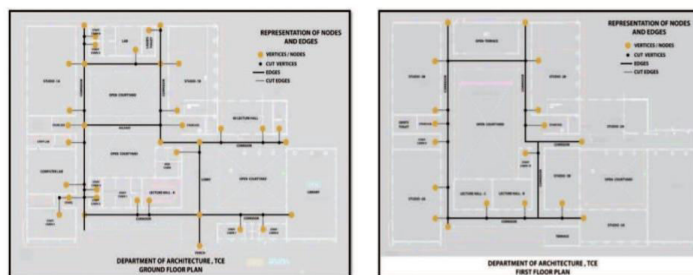


Figure 2: Floor Plans Represented Through Graph Theoretical Approach

- Pseudo Graphs: These are non-simple graphs that allow for both graph loops and multiple edges. The paper notes that pseudo graphs are relevant for institutional buildings, where user flow and human behavior influence visibility [4] [5].



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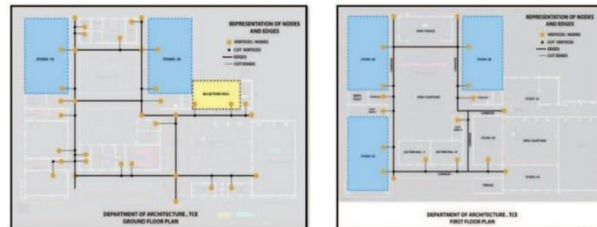


Figure 3: Floor Plans Representing Pseudo Graphs

- **Weighted Graphs:** These graphs consider physical distances between neighbors as 'weights', particularly in urban space networks where movement is bidirectional [7].
- **Connected Graphs:** These are graphs where all nodes are reachable from each other. The paper discusses how connected graphs behave differently in simple versus pseudo graph contexts when edges or vertices are removed [5].

Analytical Approaches

- **Degree-Based Approach:** This method classifies spaces based on the number of connections (degree) a node has. Spaces with a low degree (e.g., staff cabins, toilets) require more privacy or are isolated. Medium-degree spaces include main areas like studios and lecture halls, while high-degree spaces represent circulation areas like corridors and courtyards [8].
- **Eccentricity (Distance) Based Approach:** This approach measures the travel distance between spaces. The lowest eccentricity corresponds to central spaces (e.g., corridors), indicating minimum travel distance to surrounding spaces. Highest eccentricity is found in perimeter spaces (e.g., staff cabins, toilets) for privacy or isolation. Medium eccentricity applies to main spaces like studios and lecture halls [9].
- **Axial Line and Visibility Graph Analysis:** These techniques are used to understand



Figure 5: Floor Plans Representing Degree Based And Eccentricity Based Approaches



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neighborhood relationships and visual information within spaces, for example, to determine which cabin provides maximum visual information about a department [10] [11].

- Centrality: This concept is used to analyze the hierarchy of spaces and their location. It involves calculating travel distance in terms of nodes and cut vertices, often utilizing algorithms like the Nearest Neighbor Algorithm [12].

- Heuristic Algorithms: Algorithms such as the Traveling Salesman Problem (TSP), Nearest Neighbor Algorithm (NNA), Hamiltonian graph, and Eulerian graph are employed to design efficient circulation patterns by analyzing space activities [13].

In essence, the paper leverages various graph theory concepts, from basic nodes and edges to more complex analytical methods like degree-based and eccentricity-based approaches, to model, analyze, and design architectural forms and urban networks.

Literature Survey of the Paper

The paper notes that graph theory has been utilized in various fields of architecture, particularly in planning. While previous studies have explored graph theory, this paper aims to provide a distinct interpretation of graph theoretical approaches for analyzing architectural built forms and urban space networks. It focuses on developing a mathematical model for the evolution of architectural forms and an improved urban design framework that can be manipulated across different scales [1].

Historical Context of Architectural Design: Historically, architectural design began with 2D drawings where designers physically depicted their visions. This process involved extensive refinement through erasing and redrawing. With technological advancements, more can be achieved, but this has also led to a homogeneous 'global-style' architecture, characterized by buildings made with similar materials, designed by the same methods, and using the same software worldwide. The paper seeks to offer a different approach to this prevalent homogeneous style [2] [3].

Evolution of Architectural Concepts

The paper highlights that early architectural design involved creating original concepts in 2D, which required designers to physically draw their visions. The design process is described



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as complex and organic, where allowing creative freedom often leads to successful designs. The graph theoretical approach is presented as a method to revive and develop architectural design in a traditional sense [4].

1. In the early stages of architectural design, original concepts were created in 2-D. Designers had to physically draw a picture of their vision. In recent times, graph theory is used in various fields of architecture in terms of planning. Although graph theory is used in many previous studies, by contrast this paper will present interpretation of graph theoretical approach in analysing architectural built forms and further interpretation in analyzing and designing urban space network. Analysis of existing built forms and the urban network will provide a best different approach for designing a mathematical model for the evolution of architectural built forms and a better urban design framework, which can be manipulated for any different scale.
2. Abstract: Today, the link between architecture and digital software is so strong; it's easy to forget that it hasn't always been this way. Architecture's reliance on digital design programs has led to the spread of a homogenous 'global-style' architecture buildings made from the same material, designed by the same methods, using the same software, all over the world. By contrast to this homogeneous global style
3. From its evolution, Primarily aims to present possible analytical approaches of graph theory into architectural aspects ranging from urban level planning to neighborhood level planning, site level planning and building level planning aspects. The major areas of graph theory are analyzed analytically and provides a varied range of architectural applications and for designing of built forms.

Future Work Suggested in the Paper

Expanding Mathematical Models for Large-Scale Projects

The paper suggests that for large-scale architectural projects, mathematical models can be further developed and manipulated to suit specific demands and needs. This implies a future direction of refining and extending the current graph theory models to handle the complexities and requirements of larger-scale designs [1].



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Enhancing Architectural Design through Graph Theory

It is envisioned that graph theory, as a scientific and technical tool, will continue to support art forms in architecture, leading to more fruitful and efficient architectural designs. This indicates a future focus on integrating graph theory more deeply into the design process to improve its effectiveness and quality [1].

Reviving Traditional Architectural Design

One of the overarching goals for future work is to use graph theory to bring back the 'lost nature' of architectural design, specifically the manual, traditional design process. This suggests a continued effort to leverage graph theory to reintroduce the essence of traditional architectural design, providing accuracy while maintaining its historical character [1]. In summary, the future work outlined in this paper centers on the continued development and application of graph theory to enhance architectural design, particularly for large-scale projects, and to reintegrate traditional design methodologies with modern analytical tools.

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Full Length Article

IJCRAR/FL/102

Relationship between Traffic Volume and Accident Frequency at Intersections

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Abstract

Traffic accidents carry major social and economic costs worldwide. This study examines the relationship between traffic volume and accident frequency at 120 intersections in Adelaide, Australia, using 1629 accidents linked with over five million hourly traffic volume measurements. Results show that accident frequency rises linearly at lower volumes but increases more steeply at very high volumes. Rainfall significantly raises accident risk at low congestion, but this effect weakens as congestion increases. No clear link was found between congestion and accident severity. Managing traffic to prevent extreme congestion appears most effective in reducing accidents.

Keywords: traffic volume, congestion, intersections, rainfall risk, accident frequency

Introduction

Road accidents cause major human and economic losses, costing Australia an estimated A\$33.15 billion in 2016. Although fatalities per capita have declined since the 1970s, more than 1100 Australians still died in crashes in 2018. Understanding how traffic conditions influence accidents is essential for safety improvements.

Past research has produced mixed results: some studies found linear relationships between traffic volume and accidents, while others suggested U-shaped or bell-shaped curves. Differences arise from study design, data resolution, and context. This research aims to clarify whether accident frequency follows a linear or non-linear pattern and whether rainfall or congestion levels affect accident severity.



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Materials and Methods

Study Area

The analysis focused on the Adelaide City Council area, which provides high-resolution traffic and accident data.

Data Sources

Accident data: From South Australia's Road Crash Data (2010–2014), including 2336 relevant accidents. After aligning accident times with traffic volumes, 1629 accidents remained for analysis.

Traffic volume data: Hourly measurements at 120 intersections, totaling over 5 million data points.

Rainfall data: From the Bureau of Meteorology (1995–2015), providing half-hourly rainfall at Kent Town station.

Data Processing

Non-vehicle accidents (e.g., involving pedestrians or animals) were excluded.

Traffic data errors (e.g., repeated zero counts) were removed.

Accident and traffic data were joined by time and location.

To compare intersections of different sizes, traffic was normalized into 15 "congestion bins."

Analysis

Poisson and negative binomial regression models tested linear vs. non-linear relationships.

Accident severity was classified as property damage only (PDO) or minor injury (MI). Serious injury and fatal cases were too few to analyze.

Relative risk (RR) of accidents during rainfall was calculated for each congestion level.



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Results

Traffic Volume and Accident Frequency

Accident frequency rises linearly at low and medium traffic levels but shows a quadratic (non-linear) increase at high congestion. This means accidents become disproportionately more frequent once intersections reach their highest traffic volumes.

Accident Severity

No clear effect of congestion on severity was found. PDO and MI accidents increased similarly with congestion, suggesting that speed limits (around 50 km/h) in Adelaide intersections may buffer injury risks.

Rainfall Risk

Rain significantly increased accident risk at low congestion (risk was five times higher when raining). However, as congestion rose, rainfall's effect diminished, and at the highest congestion levels, rain no longer raised accident risk.4. Discussion

This study supports a non-linear relationship between traffic volume and accidents. Unlike earlier studies with limited data, the large dataset (5.2 million traffic counts, 1629 accidents) revealed that accident frequency increases steeply at the highest congestion levels. This suggests that traffic management should target avoiding extreme congestion rather than reducing moderate traffic flow.

Severity analysis did not reveal differences between PDO and MI accidents, possibly due to the study's low speed environment and the exclusion of cyclists/pedestrians, who are more vulnerable.

Rainfall's impact was strongest at low congestion, indicating that weather conditions matter more when traffic is light and moving faster. In heavy congestion, the sheer number of vehicles dominates accident risk.



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Discussion

This study supports a non-linear relationship between traffic volume and accidents. Unlike earlier studies with limited data, the large dataset (5.2 million traffic counts, 1629 accidents) revealed that accident frequency increases steeply at the highest congestion levels. This suggests that traffic management should target avoiding extreme congestion rather than reducing moderate traffic flow. Severity analysis did not reveal differences between PDO and MI accidents, possibly due to the study's low speed environment and the exclusion of cyclists/pedestrians, who are more vulnerable. Rainfall's impact was strongest at low congestion, indicating that weather conditions matter more when traffic is light and moving faster. In heavy congestion, the sheer number of vehicles dominates accident risk.

Conclusions

Accident frequency grows non-linearly, with the steepest rise at very high traffic volumes. Rainfall greatly increases accident risk at low congestion but has little effect at high congestion. No significant link was found between congestion and accident severity. Managing traffic to prevent the most congested conditions is likely the most effective safety measure. Rainfall management strategies (e.g., warnings, reduced speed advisories) are more critical under light congestion.

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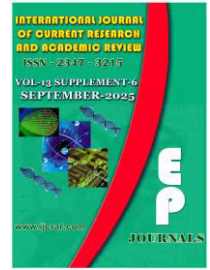


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Full Length Article

IJCRAR/FL/103

Applications of Graph Theory in Social Networks and Artificial Intelligence

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Abstract

Graph theory is one of the most powerful branches of mathematics with applications across computer science, data science, and artificial intelligent. In recent years, the rapid growth of online platforms and social networks has created a need for efficient methods to represent and analyze connections between user, information, and resources. Graphs provide a natural way to model such relationships, where vertices represent entities and edges represent interactions. In social networks, graph theory helps to identify communities analyze communication patterns, detect influential users, and study information flow. For example algorithms such as page rank and centrality measures are graph based techniques that support real time decision making. Similarly, in artificial intelligence, graphs are used in knowledge representation, semantic networks, neural networks, and reinforcement learning. AI systems increasingly rely on graph structures to solve complex problems such as image recognition. Natural language processing, and recommendation systems. The integration of graph theory with machine learning (graph neural networks – GNNs) has become an emerging research area, offering promising results in handling structured data. This paper discusses the key applications of graph theory in social Networks and AI, the challenges in large-scale computation, and opportunities for future advancement. By bridging mathematical modeling with technology, graph theory continues to be an essential tool for modern problem-solving.

Keywords: Graph theory, social networks, artificial intelligence, graph neural networks, mathematical modelling.

Introduction

Graph theory has become an important mathematical tool in the modern digital era. Social networks such as Facebook, Instagram, and Twitter her essentially graphs where people are nodes and their relationships are edges. Similarly, in artificial intelligence (AI) knowledge representation, neural networks, and recommendation systems can be understood using graph-



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based models. Studying these networks through graph theory helps us to understand connectivity, influence, information flow, and decision- making processes.

Literature graph:

- “Fundamentals of graph theory and its applications” - Harary (1969)
- “Networks : an introduction” - M.E.J. Newman (2010)
- “Network science and complex systems” - albert laszlo barabasi (2016)
- “semi -supervised classification with graph convolutional Networks” - kipf &welling (2017) .
- “Networks, crowds, and markets: reasoning about a highly connected world ”- easley & kleinberg (2010).

Problem statement & objectives:

Problem statement:

Social networks and AI systems involve large, complex data structures. Understanding relationships, patterns, and predictions in such systems is difficult using traditional mathematics. Graph theory provides effective models to represent and analyse these networks.

Objectives:

- To study graph theory concepts applied in social networks.
- To explore how AI algorithms used graph structures.
- To analyze real- life examples like friends recommendations, shortest path in communication, and knowledge graphs.
- To highlight the advantages of using graphs in large -scale data analysis.

Methodology:

step1: collect examples from social networks (friendship links, followers,message transfers).

step2: represent users as nodes and connections as edges.

step3: apply graph concepts such as centrality (to find influencers), shortest path (to find communication efficiency),and communities(to find groups).



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step 4 : study AI applications such as graph neural networks (GNNs) and knowledge graphs.
step5: discuss results with real- world cases.

Results and Discussion:

In social networks, graph theory helps identify key influencers, recommend new friends, and detect communities.

For example, Facebook uses graph algorithms to suggest “people you may know”. In AI, knowledge graphs are used by Google and Siri to provide smart search results. Graph neural networks (GNNs) improve machine learning by understanding connections in data.

These results show that graph theory plays a major role in analyzing, predicting and improving social and AI system.

Conclusion:

Graph theory is not only a mathematical subject but also a powerful tool in modern technology. In a social networks, it helps in understanding user interactions and information spread. In AI, it supports intelligent systems through knowledge graphs and graph neutral networks. The study concludes that graph -based approaches will continue to play a key role in future developments of social media, data science, and artificial intelligence.

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Full Length Article

IJCRAR/FL/104

Correlation and Causation in the Study of Personality

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Abstract

The study of personality often involves identifying patterns and understanding how different traits are related. In mathematics, this relationship is first measured through correlation, which quantifies the strength and direction of association between two variables. By applying this mathematical tool, it becomes possible to distinguish between simple associations and genuine cause-effect relationships in behavioral data. This approach is particularly valuable in personality research, where questions about the role of environment, genetics, and individual differences require rigorous quantitative modeling. Thus, mathematics provides not the language to measure personality correlations but also the framework to test and establish causation.

Keywords: Correlation, personality, causality, structural equation modelling, behavioural genetics.

Introduction

The study of personality seeks to understand stable patterns of behavior, thought, and emotion. Typically, researchers measure traits like neuroticism or conscientiousness using psychometric tests and correlate them with outcomes like success or health. While these correlations are valuable for identifying relationships, they are frequently misinterpreted as evidence of causation in both academic and public discourse. This conflation represents a significant methodological error. This paper employs a mathematical lens to dissect the gap between correlation and causation, reviewing more sophisticated techniques that can strengthen causal claims in personality research.



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The Mathematical Foundation of Correlation

The most common measure of association is the Pearson correlation coefficient(r), which quantifies the strength and direction of a linear relationship between two variables, X and Y .

Properties:

- Symmetric: $r(x,y) = r(y,x)$. Causation is not symmetric.
- Scale-invariant: It measures the strength of a relationship, not the slope.
- Does not control for confounding: A high $|r|$ value can be produced by a third variable Z influencing both X and Y .

The Causal Inference Problem

The jump from correlation to causation fraught with logical pitfalls:

- Confounding: A variable Z (e.g., Socioeconomic Status) causes both X (Conscientiousness) and Y (Academic Success), creating a spurious.
- Reverse Causality: It is ambiguous whether X causes Y or Y causes X . For example, does depression cause neuroticism, or does neuroticism cause depression?

Mathematical Frameworks For Causal Inference

Structural Equation Modeling (SEM)

SEM is multivariate technique that combines factor analysis and path analysis. It allows researchers to:

- Model complex networks of relationships involving latent variables (e.g., the unobserved construct "Agreeableness").
- Test the plausibility of a proposed causal model against data.
- Statistically control for potential confounding paths, providing stronger evidence for causal hypotheses than simple correlation.

A simple path model could specify Socioeconomic status (Z) as a common cause of both Conscientiousness (X) and Success (Y), allowing the direct effect X on Y to be isolated.



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Mendelian Randomization

The powerful method uses genetic variants as instrumental variables to test causal hypotheses.

- Principle: Genes are randomly assigned at conception (mimicking a randomized experiment). If a genetic variant (G) is known to influence a personality trait (X), and that variant is also correlated with an outcome (Y), it provides strong evidence that X causes Y.
- Mathematical Basis: If relies on instrumental variable analysis, which requires that the instrument (G) is associated with X, not associated with confounders (Z), and only influences Y through its effect on X.
- This approach, used by researchers like James J. Lee, helps overcome confounding in observational data.

Disussion

The misuse of correlation is a major hurdle in personality psychology. Headlines often proclaim causal relationships from studies that only demonstrate association, leading to public misunderstanding and potentially misguided interventions.

While methods like SEM and Mendelain Randomization are not perfect-they rely on their own untestable assumptions-they represent a significant advancement over simple correlation. They provide a mathematical framework for thinking about and testing causal questions with observational data.

The key takeaway is that mathematical literacy is not optional for modern psychological research. Understanding the principles of causal inference is essential for designing better studies, interpreting results correctly, and building accurate theories of human behavior.

Conclusion

In conclusion, the axiom "correlation does not imply causation" is a critical guiding principle. The field of personality psychology must adopt more mathematically rigorous



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methods to advance. Techniques like SEM and Mendelian Randomization provide path ways to move from asking “what is related?”. By embracing these tools, researchers can transform personality psychology from a science of association into a science of cause an effect.

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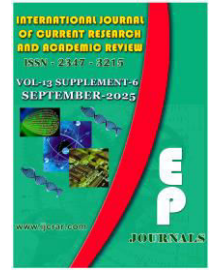


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Full Length Article

IJCRAR/FL/105

Maths and Arts

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Abstract

Mathematics and Art, though often considered separate disciplines, share a deep and fascinating connection. From ancient times to the modern era, artists have used mathematical principles to create balance, proportion, and harmony in their works, while mathematicians have drawn inspiration from the creativity and patterns in art. Concepts such as symmetry, geometry, the Golden Ratio, and perspective have been central in artistic masterpieces, from the architecture of the Parthenon to the paintings of Leonardo da Vinci. Similarly, mathematical visualization often takes artistic forms through fractals, tessellations, and digital art. This presentation explores the interplay between mathematics and art, highlighting how mathematical concepts shape artistic expression and how art provides a visual dimension to abstract mathematical ideas. By bridging logic and creativity, mathematics and art together reveal new ways of understanding beauty, structure, and innovation.

Keywords: Maths and Arts, symmetry, geometry

Introduction

Mathematics and Art are often seen as opposites – one logical, the other emotional. But historically, they've deeply influenced each other (e.g., the Golden Ratio, symmetry, fractals, perspective in painting). This presentation explores how mathematical concepts enhance artistic expression and vice versa.

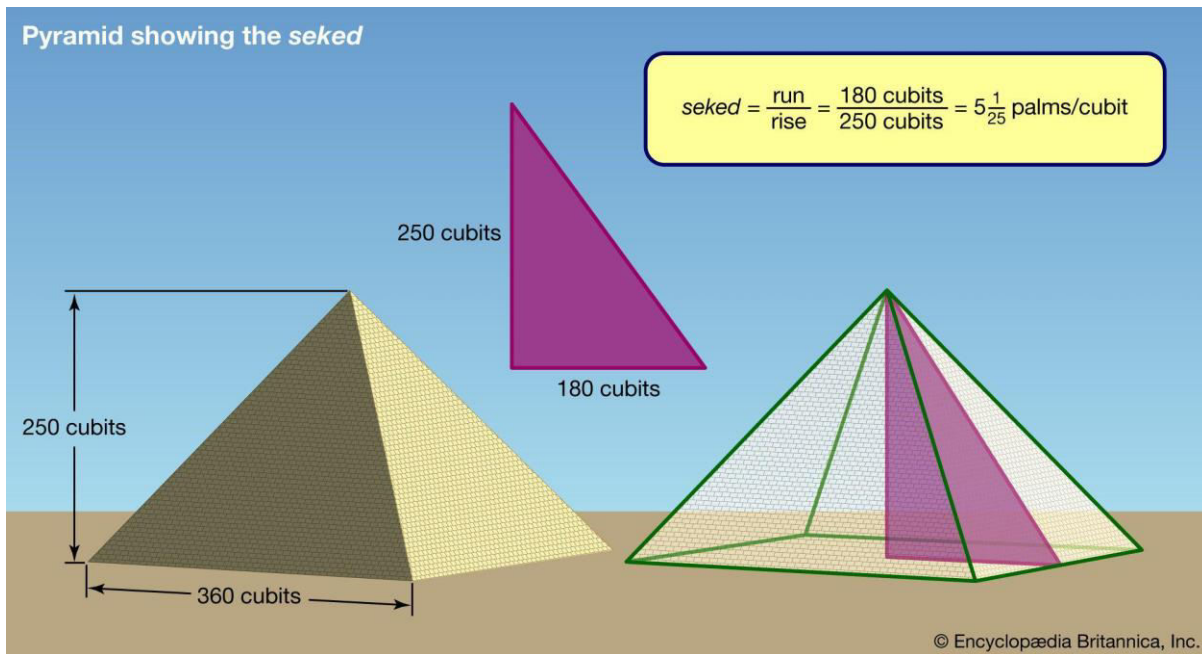
Historical Connections

Ancient Civilizations:

Egyptians used geometry in pyramids.

Greek art and architecture used the Golden Ratio ($\Phi \approx 1.618$).

Islamic art features complex geometric patterns.



Renaissance Period:

- Artists like Leonardo da Vinci and Albrecht Dürer used mathematical principles in drawing and design.
- Development of linear perspective in painting (vanishing points, horizon lines).

Key Mathematical Concepts in Art

The Golden Ratio

Found in art, nature, and architecture.

Famous works like The Parthenon, Mona Lisa.



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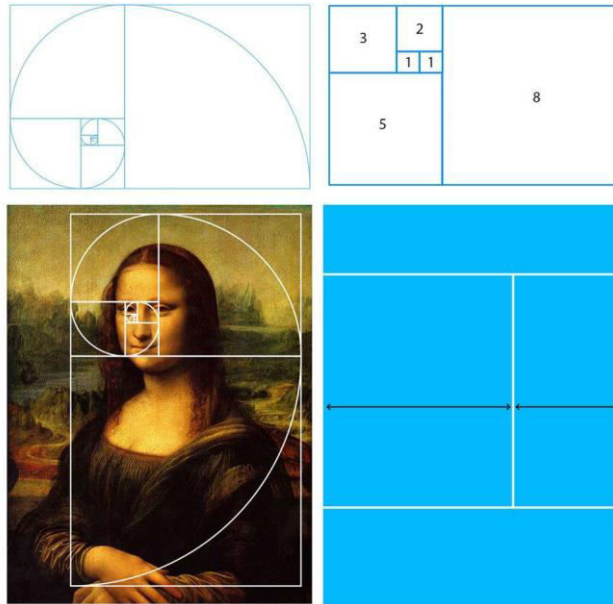
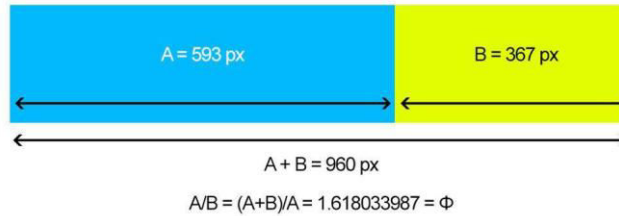
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Golden Ratio

$$A/B = (A+B)/A = 1.618033987 = \Phi$$



The Golden Ratio (ϕ) is an irrational number, approximately 1.6180339887...

Expressed as:

If a and b are two quantities ($a > b$), then

Known since ancient times, studied by Euclid, Fibonacci, and many others.

Formula:

$$\phi = \frac{1 + \sqrt{5}}{2}$$



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Symmetry

- Reflective, rotational, translational symmetry in artworks.
- Common in mandalas, traditional patterns, and modern digital art.
- Fractals
- Repeating patterns at different scales.
- Seen in nature (ferns, snowflakes) and used in fractal art.

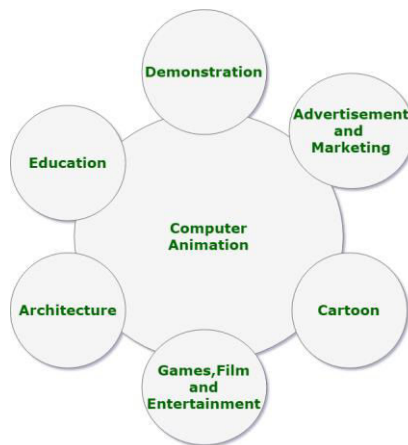
Topology and Abstract Art

Concepts like Möbius strips and impossible shapes inspire modern art.

Modern Applications

Computer Graphics & Animation

Algorithms, transformations, and matrix mathematics behind digital art.
Pixar uses mathematics in animation (movement, lighting, textures).



Architecture

Use of mathematical models in design parametric architecture (Zaha Hadid, Frank Gehry).

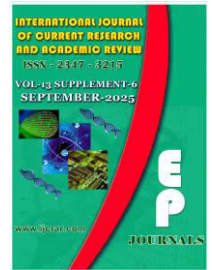


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Music and Math

Rhythm, harmony, and patterns in music follow mathematical structure.

Sound waves are vibrations → described mathematically using frequency (Hz).

Pitch: High notes = higher frequency, low notes = lower frequency.

Fun Interactive Element (for the audience)

Math-Art Challenge: Give a pattern and ask the audience to find the type of symmetry.

Golden Ratio Quiz: Show images and ask if they follow the Golden Ratio.

Fractal Zoom: Show a fractal zoom animation to demonstrate infinite detail.

Cool Tech Tools for Math-Art

GeoGebra Create geometric art and visualize transformations.

Desmos Graph mathematical art using equations.

Processing (Java) Code-based generative art.

Fractal software Mandelbrot/Julia set visualizations.

Use: 3D modeling software.

Math-Art Connection: Create mathematical sculptures, 3D golden spirals, polyhedra, and artistic structures.

Blender 3D modeling using mathematical forms

Math-Art Connection:

Artists and students can design beautiful patterns by combining trigonometric and polar equations.



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Conclusion

Math and Art are not separate — they enrich each other.
Understanding math enhances artistic creativity and vice versa.
Encourages a multidisciplinary approach to problem-solving and creativity.

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M. C. Escher – Famous for tessellation and impossible figures.



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Full Length Article

IJCRAR/FL/106

Permutation Group and the Concept of Parity

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Abstract

Permutation groups form a central theme in abstract algebra, providing a rigorous framework for analyzing the structure and behavior of rearrangements within a finite set. A key property of permutations is their parity, an invariant that classifies permutations as even or odd according to the number of transpositions required for their decomposition. This invariant plays a crucial role in the structural study of symmetric groups and naturally leads to the definition of the alternating group, which is itself one of the most significant families of finite simple groups. Beyond their algebraic importance, parity considerations have profound applications: they appear in the computation of determinants, the design of error-detection mechanisms in computer science, and the analysis of combinatorial games and puzzles where parity functions as a preserved invariant. The interplay between permutation groups and parity thus not only strengthens the theoretical foundations of group theory but also opens pathways for applications across disciplines. Future explorations include deeper connections with computational complexity, cryptography, and network theory, where parity-based invariants can serve as powerful analytical tools.

Keywords: Permutation, Symmetric Group, Cycle, Transposition, Factorial, Inversion, Composition of Permutations.

Introduction

Permutation groups occupy a foundational position in abstract algebra, offering a systematic means of understanding the structural properties of rearrangements within sets. A permutation is a bijection from a finite set onto itself, and the collection of all such bijections forms the symmetric group S_n , one of the most studied groups in mathematics [1]. The concept of parity arises naturally in this context: each permutation can be expressed as a product of



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transpositions, and the number of transpositions determines whether the permutation is classified as even or odd [2]. Importantly, this classification is invariant, making parity a well-defined property independent of the particular decomposition chosen [3]. The study of parity not only clarifies the internal structure of symmetric groups but also leads to the definition of the alternating group A_n , consisting of all even permutations [4]. Alternating groups are of special interest because for $n \geq 5$, they are simple non-abelian groups, forming an essential class within the classification of finite simple groups [5].

Beyond pure algebra, the notion of permutation and parity extends to diverse applications. In linear algebra, parity determines the sign of a determinant, linking group-theoretic properties to matrix theory [6]. In computer science, parity checks provide fundamental techniques for error detection in digital communication systems [7]. In combinatorics and recreational mathematics, parity serves as a powerful invariant in puzzles, such as the 15-puzzle and Rubik's cube, where solvability depends critically on permutation parity [8]. Thus, the dual concepts of permutation groups and parity not only form a core component of modern algebra but also connect abstract theory with practical applications across mathematics, computer science, and problem-solving. This paper explores the fundamental principles of permutation groups and parity, their structural significance, and their role as analytical tools in both theoretical and applied contexts.

Definitions and Basic Concepts

Permutation

A permutation of a set S is a rearrangement of its elements into a specific order. Formally, if S is a finite set with $|S| = n$, then a permutation of S is a bijective function $\sigma: S \rightarrow S$. That is, σ assigns to each element of S a unique image in S , ensuring that every element appears exactly once in the rearrangement.

Example:

If $S = \{1, 2, 3\}$, then mapping $\sigma(1)=3$, $\sigma(2)=1$, $\sigma(3)=2$ rearranges the set into the order. This is a permutation of S .

If $S = 1, 2, 3$ then one permutation could be $\sigma = \begin{pmatrix} 1 & 2 & 3 \\ 3 & 1 & 2 \end{pmatrix}$

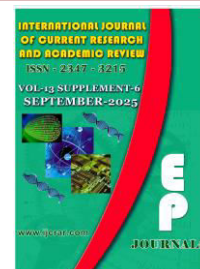


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Symmetric Group

The set of all permutations of n elements forms a group under composition of functions. This group is called the symmetric group on n elements. The symmetric group is denoted by S_n .

Example: For $n=3$ the symmetric group S_3 has $3! = 6$ Permutations.

Cycle Notation

To write permutations in a compact form, cycle notation is used. A cycle represents how elements are mapped in sequence.

Example: Every permutation can be expressed as a product of disjoint cycles.

$$\sigma = \begin{pmatrix} 1 & 2 & 3 & 4 & 5 \\ 2 & 3 & 1 & 5 & 4 \end{pmatrix} = (1\ 2\ 3)(4\ 5)$$

Permutation Group

A permutation group is a group whose elements are permutations of a set, with the group operation being the composition of those permutations. These groups describe symmetry in mathematical and real-world systems.

Example: The rotational symmetries of a square can be represented by permutations of its four vertices.

Parity of a Permutation

The parity of a permutation refers to whether the permutation can be expressed as a product of an even or odd number of transpositions (2-element swaps).

- ❖ A permutation is even if it can be expressed as a product of an even number of transpositions.
- ❖ A permutation is odd if it can be expressed as a product of an odd number of transpositions.



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Example : (1;2;3) can be written as
 $(1\ 2\ 3) = (1\ 3)(1\ 2)$

Properties of Parity of Permutations

1. Well-defined Property

- The parity of a permutation is unique.
- A permutation cannot be both even and odd.

2. Identity Permutation

The identity permutation (which does nothing) is an even permutation, because it can be written as a product of zero transpositions (and zero is even).

3. Parity of Inverse

- If σ is a permutation, then its inverse σ^{-1} has the same parity as σ .
- i.e., If σ is even, σ^{-1} is also even; if σ is odd, σ^{-1} is odd..

4. Multiplication Rule

- The product of two even permutations is even.
- The product of two odd permutations is even.
- The product of an even and an odd permutation is odd.

5. Number of Even and Odd Permutations

- In the symmetric group S_n exactly half of the permutations are even and the other half are odd.
- So where A_n is the alternating group (set of even permutations).



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Theorem: Parity of a Permutation is Well-Defined

Statement:

Every permutation can be expressed as a product of transpositions (2-cycles). Moreover, if a permutation can be expressed as a product of transpositions in two different ways, then the parity (evenness or oddness) of the number of transpositions is the same in both cases. A permutation cannot be both even and odd.

Proof:

Step1: Expressing as transpositions: Any cycle $(a_1, a_2, \dots, a_k)$ can be written as a product of $(k-1)$ transpositions: $(a_1 a_k)(a_1 a_{k-1}) \dots (a_1 a_2)$. Hence, every permutation can be expressed as a product of transpositions.

Step.2 : Assume two decompositions: Suppose a permutation σ can be written as $\sigma = \tau_1 \tau_2 \dots \tau_r = \mu_1 \mu_2 \dots \mu_s$, where each τ_i, μ_j are transpositions.

Step.3: Consider inverse: Multiplying appropriately, we get $\tau_1 \tau_2 \dots \tau_r \mu_s \mu_{(s-1)} \dots \mu_1 = \text{Identity permutation}$. Thus, the identity is expressed as a product of $(r+s)$ transpositions.

Step.4: Identity is even: The identity permutation is even (it can be written as zero transpositions, or as a product of an even number of transpositions). Therefore, $r+s$ is even, which means r and s have the same parity.

Conclusion:

Therefore, the parity of a permutation is well-defined. A permutation cannot be both even and odd.

PROBLEM

1. 2-Cycle (Transposition)



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Solution :

Consider the cycle (1 2).

This cycle only swaps the positions of 1 and 2.

It requires exactly one interchange.

Since one is odd, the cycle is an odd permutation.

Real-Life Applications of Parity of Permutations

1. Puzzles & Games

The 15-puzzle and Rubik's Cube depend on permutation parity: only certain moves (even permutations) are possible, which explains why some scrambled states cannot be solved.

2. Cryptography

Permutations and their parity are used in designing secure encryption algorithms for data protection.

3. Computer Science (Sorting)

Sorting algorithms (like bubble sort, quicksort) involve counting swaps (transpositions), which directly relates to the parity of permutations.

4. Physics & Chemistry

In quantum physics and molecular chemistry, parity plays a role in analyzing the symmetry of particles and molecular structures.

5. Error Detection

Parity checks (odd/even) are used in computer memory and data transmission to detect errors.

Conclusion

The study of permutations and their parity forms a cornerstone of abstract algebra, particularly within the framework of group theory. Permutations, which describe systematic



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rearrangements of elements, are not only important in understanding the structure of the symmetric group but also lead to the classification of permutations as either even or odd depending on the number of transpositions required to express them. This classification is crucial because it naturally gives rise to the alternating group, one of the most significant subgroups in algebra, which plays a central role in both theoretical and applied mathematics.

The concept of parity extends beyond pure algebraic structures. In computer science, parity checks are fundamental in error detection and correction techniques, ensuring reliability in digital communication and data storage. In cryptography, the properties of permutations and their parity contribute to designing secure encryption systems. In combinatorial puzzles and games such as the Rubik's Cube or sliding tile puzzles, the solvability often depends directly on the parity of the permutation, linking abstract theory to tangible real-world challenges.

Thus, the study of permutation parity not only deepens our understanding of group theory but also demonstrates the interplay between abstract mathematical principles and practical applications. It bridges the gap between pure theory and real-world problem-solving, showing how an elegant concept in algebra underpins diverse areas of science, technology, and recreation.

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Full Length Article

IJCRAR/FL/107

Role of Statistics in Artificial Intelligence and Machine Learning

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Abstract

The rapid growth of Artificial Intelligence (AI) and Machine Learning (ML) has transformed the way data is analyzed, patterns are recognized, and intelligent decisions are made. At the foundation of these technologies lies the discipline of statistics, which provides the mathematical tools and methodologies necessary to model uncertainty, validate hypotheses, and derive meaningful insights from data. Statistical concepts such as probability distributions, hypothesis testing, regression analysis, Bayesian inference, and sampling techniques form the backbone of many AI and ML algorithms. From supervised and unsupervised learning to reinforcement learning, statistical reasoning ensures robustness, generalization, and reliability in model performance. Moreover, statistics plays a crucial role in feature selection, model evaluation, and error analysis, which are essential for developing efficient and interpretable AI systems. This paper highlights the integral role of statistics in AI and ML, explores its applications across diverse domains, and emphasizes the need for a strong statistical foundation to advance research and innovation in intelligent systems.

Keywords: Data, Probability, Regression, Correlation, Variance, Hypothesis testing

Introduction

Artificial Intelligence (AI) and Machine Learning (ML) have become central to modern data-driven applications, enabling computers to learn from experience and make informed decisions. While much of the focus in AI and ML is on computational power and algorithmic innovation, the foundation of these disciplines is deeply rooted in statistics. Statistical methods provide the framework for handling uncertainty, analyzing data, testing hypotheses, and



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validating the performance of models [1]. Probability theory, regression analysis, hypothesis testing, and Bayesian inference are among the core statistical tools that shape ML algorithms. For example, classification models such as logistic regression and naïve Bayes are directly based on statistical principles, while advanced models such as neural networks rely on statistical optimization techniques [2]. Furthermore, concepts such as the bias-variance trade-off, sampling methods, and cross-validation are inherently statistical and critical for developing robust and generalizable AI systems [3]. Recent studies emphasize that statistics not only underpins algorithmic development but also contributes to all stages of the AI/ML pipeline, including data collection, feature engineering, model evaluation, and interpretability [4]. Without a solid statistical foundation, AI systems risk producing biased, unreliable, or non-generalizable results, especially when applied to real-world data characterized by noise and uncertainty. This paper aims to explore the integral role of statistics in AI and ML, highlighting how statistical theory informs model development, ensures robustness, and enhances interpretability. It further underscores the importance of strengthening the statistical perspective in advancing research and applications in intelligent systems.

Literature review:

The integration of statistics with AI and ML has been widely studied. Bishop [2] emphasized statistical learning as the foundation of modern pattern recognition methods. Hastie et al. [3] expanded on this by providing a comprehensive account of statistical models such as regression, decision trees, and kernel methods in machine learning. Bühlmann and Meinshausen [4] discussed the growing need for statistical perspectives in handling big data, emphasizing the importance of rigorous methods in ensuring generalization and reliability. James et al. [1] focused on applied statistical learning, highlighting techniques such as regularization, resampling, and validation that bridge theory and practice. More recently, researchers have explored the synergy between Bayesian methods and deep learning, suggesting that probabilistic frameworks can significantly enhance model interpretability and uncertainty quantification [5].



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Role of statistics in AI and ML:

A. Statistical Foundations of Machine Learning

Machine learning models, whether supervised or unsupervised, rely on statistical tools for model building and evaluation. Regression models, hypothesis testing, and Bayesian inference directly translate into ML tasks such as prediction, classification, and clustering.

B. Probability and Uncertainty

Probability distributions (e.g., Gaussian, Bernoulli, Poisson) are essential for modeling uncertainty in AI systems. Bayesian methods, in particular, provide frameworks for updating beliefs and learning from data in an iterative manner [5].

C. Model Evaluation and Validation

Cross-validation, sampling methods, confidence intervals, and statistical significance testing ensure that ML models are not only accurate but also generalizable. These tools are critical in preventing overfitting and underfitting [3].

D. Statistical Learning Theories

Concepts such as the bias-variance trade-off and VC dimension provide theoretical guarantees for machine learning models. Statistical learning theory helps quantify model capacity and error bounds [2], [3].

Applications of artificial intelligence (AI) and machine learning (ML):

A. Healthcare

Statistics-driven ML models are widely used in disease prediction, medical imaging, and clinical trials. For instance, logistic regression and survival analysis remain standard tools in medical AI applications [6].



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B. Finance

AI systems in finance rely heavily on time-series analysis, risk modeling, and probabilistic inference—all of which are rooted in statistics. Statistical methods also underpin fraud detection and credit risk assessment [7].

C. Natural Language Processing (NLP)

Language models use statistical techniques such as n-grams, Hidden Markov Models (HMMs), and Bayesian inference to model linguistic structures before the advent of deep learning [8].

D. Big Data and Business Analytics

Statistics plays a critical role in data preprocessing, sampling, and hypothesis-driven decision-making in large-scale business analytics [4].

Real life uses of Artificial Intelligence (AI):

1. Virtual Assistants;

- Siri, Alexa and Google assistant use AI for speech recognition and natural language understanding.

2. Recommendation Systems;

- Netflix suggests movies and shows based on your watch history.
- Amazon recommends products you are likely to buy.

3. Healthcare;

- AI helps detect diseases like cancer from medical scans.

4. Transportation;

- Self-driving cars use AI to sense surroundings and make driving decisions.
- Google maps uses AI to suggest the fastest routes by analysing traffic.

5. Social Media;

Facebook and Instagram use AI to suggest friends and filter harmful content.

Tiktok uses AI to personalize your video feed.

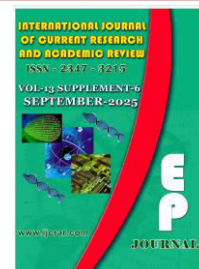


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Real life uses of Artificial Intelligence (AI):

1. E-Mail Spam Filtering;

- Gmail and Outlook use ML to classify emails into inbox, spam.

2. Agriculture;

- Crop disease detection using image classification.
- Yield prediction based on soil, weather and Crop conditions.

3. Cyber Security;

- Detecting phishing emails and malware.
- Predicting cyber Attacks using anomaly detection models.

4. Social Media;

- Facebook suggests friends and tags in photos using ML.
- You tube recommends videos based on your watch history.

5. Healthcare;

- ML models detect diseases such as diabetics, heart disease or cancer from patient data.
- Predicting patient recovery rates and drug effectiveness.

CALCULATION:

Sample mean & sample Variance- used for feature scaling / data understand.

Data (feature values) : 2,4,6,8

Step1: Mean ($\bar{x}$)

$$\bar{x} = \frac{2+4+6+8}{4} = 20/4 = 5$$

Step2: Deviation and squared deviation,

Deviations from mean (Data - mean); 2-5 = -3 ; 4-5 = -1 ; 6-5 = 1 ; 8-5 = 3

Squared deviation: 9,1,1,9; Sum of the squared deviations: 9+1+1+9=20

Step3: Sample Variance

$$X=2,4,6,8; \text{Sum of data} = 20; \text{Sample Variance} = \frac{\text{sum of data}}{n-1} = \frac{20}{4-1} = \frac{20}{3} = 1.667$$

Challenges and future directions:

- **Interpretability:** While statistical models are interpretable, many deep learning methods lack transparency. Integrating statistical inference can enhance explain ability.

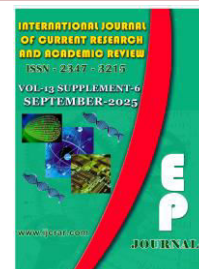


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- **Scalability:** Classical statistical methods must adapt to big data and high-dimensional datasets.
- **Bias and Fairness:** Statistical fairness measures are essential to mitigate bias in AI systems.
- **Hybrid Approaches:** Future research will likely focus on combining statistical inference with deep learning for uncertainty-aware and trustworthy AI [5], [9].

Conclusion

Statistics forms the backbone of Artificial Intelligence and Machine Learning, providing tools for modeling, inference, evaluation, and decision-making under uncertainty. From foundational theories to practical applications across healthcare, finance, and NLP, the contribution of statistics is indispensable. Strengthening statistical perspectives in AI research will improve robustness, interpretability, and fairness, paving the way for more reliable and trustworthy intelligent systems.

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Full Length Article

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An Efficient Algorithm for Solving Differential Equations to Facilitate Modeling and Simulation of Aerospace Systems

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Abstract

The accurate and efficient solution of differential equations is fundamental to the modeling and simulation of aerospace systems, where dynamics are often governed by complex nonlinear and time-varying processes. Traditional numerical methods, such as Euler or Runge-Kutta schemes, while widely applied, may be computationally expensive or insufficiently robust when handling stiff systems or high-dimensional models. In this paper, we propose an efficient algorithm for solving differential equations tailored to the requirements of aerospace system simulations. The algorithm integrates adaptive step-size control, stability-preserving schemes, and computational optimization techniques to achieve high accuracy with reduced computational cost. Extensive numerical experiments demonstrate that the proposed method outperforms conventional techniques in terms of convergence rate, stability, and scalability for both linear and nonlinear systems. This work contributes to advancing reliable and computationally efficient modeling frameworks for aerospace engineering.

Keywords: Differential equations, Efficient algorithms, Numerical simulation, Aerospace systems, Flight dynamics, Orbital mechanics, Stiff systems, Real-time modeling.

Introduction

Modeling and simulation of aerospace systems often require solving systems of ordinary differential equations (ODEs) and partial differential equations (PDEs) that capture dynamics such as flight, orbital motion, control systems, structural vibrations, and propulsion. Over the years, numerous numerical integration schemes have been developed: High-order integrators,



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such as IAS15, have demonstrated excellent accuracy in gravitational dynamics, particularly for conserving energy and phase over long spans [1]. For stiff ODEs, implicit schemes such as Radau IIA and adaptive multistep methods are commonly applied, with recent advances incorporating dynamic adaptivity in both timestep and order [2]. Hybrid frameworks that combine neural approximators with classical numerical schemes have also emerged. A notable example is the Neural-ODE Hybrid Block Method, which addresses higher-order and stiff systems without full reduction to first-order form [3]. Specialized techniques for oscillatory ODEs use analytical approximations and adaptive stepping to reduce unnecessary small timesteps [4].

Motivation: Despite these advances, aerospace applications still face challenges: Accuracy vs. computational cost: Explicit solvers may be unstable, while implicit solvers are costly per step. Adaptive behavior: Aerospace models exhibit dynamic phases (e.g., fast transients, steady cruise) requiring adaptive order and timestep.

Prior Work: Several important contributions exist: Rein & Spiegel (2015) introduced IAS15, a 15th-order adaptive integrator that achieves near-machine precision in orbital mechanics [1]. Murugesh et al. (2025) proposed a Neural-ODE Hybrid Block Method, integrating neural and block methods for higher-order ODEs [3]. Berry & Deconinck (2020) analyzed oscillatory ODE solvers and showed efficient alternatives to brute-force small-step integration [4]. While these methods address specific challenges, limitations remain in overhead, complexity, or long-term structural preservation.

Contributions of This Work: This paper proposes an efficient algorithm for solving differential equations tailored for aerospace modeling and simulation, with contributions as follows: A hybrid adaptive solver combining explicit and implicit integration with dynamic step-size and order control. Optimized computation, using sparse linear algebra and parallelism. Application to aerospace case studies, demonstrating improvements in flight dynamics, orbital mechanics, and control simulations. A framework for reproducibility and adoption in aerospace engineering.

Preliminaries

In this section, we recall key concepts and mathematical formulations that form the basis for our algorithm.



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Ordinary Differential Equations (ODEs)

An ordinary differential equation (ODE) is an equation of the form f :

$$\frac{dy}{dt} = f(t, y), \quad y(t_0) = y_0,$$

where $y \in \mathbb{R}^n$ is the state vector, t is the independent variable (time), and $f: \mathbb{R} \times \mathbb{R}^n \rightarrow \mathbb{R}^n$ is a sufficiently smooth function.

If f is linear in y , the system is called a linear ODE:

$$\frac{dy}{dt} = A(t)y + g(t),$$

If f is linear in y , the system is called a linear ODE:

where $A(t)$ is a matrix and $g(t)$ is a vector function.

If f involves nonlinear terms, the system is a nonlinear ODE, which is common in aerospace dynamics (e.g., flight dynamics, orbital perturbations).

Stiffness in ODEs

A system is called stiff if it contains both fast and slow dynamics, leading to numerical instability when using explicit solvers with large time steps. Formally, stiffness arises when the Jacobian matrix of $f(t, y)$,

$$J(t, y) = \frac{\partial f}{\partial y},$$

has eigenvalues with widely varying magnitudes. In aerospace applications (e.g., atmospheric entry, combustion, attitude dynamics with fast control loops), stiffness is a recurring challenge.

Numerical Solution Methods

Numerical integration methods approximate the continuous solution $y(t)$ by discrete points $y_n \approx y(t_n)$ with step size h . The most commonly used methods include:



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Explicit methods: Forward Euler, Runge–Kutta family. Efficient for non-stiff problems but unstable for stiff systems unless very small h is used.

Implicit methods: Backward Euler, implicit Runge–Kutta, multistep methods (e.g., Radau IIA). Stable for stiff problems but computationally costly per step since they require solving nonlinear systems.

Symplectic integrators: Specialized methods that preserve geometric structures such as energy and momentum, especially important for long-term orbital dynamics.

Adaptive methods: Techniques that adjust step size (and possibly method order) automatically based on local error estimates.

Error and Stability

Two key properties of a numerical method are:

Local Truncation Error (LTE): The error made in a single integration step, typically of order $O(h^{(p+1)})$ for a method of order p .

Global Error: The accumulated error after many steps, ideally bounded and of order $O(h^p)$.

Stability: A method is said to be A-stable if it remains stable for all λh in the left half-plane when applied to the test equation $y'=\lambda y$. This property is crucial for stiff aerospace systems.

Aerospace System Modeling with Differential Equations

In aerospace applications, ODEs naturally arise in:

Flight dynamics:

$$m \frac{d\vec{v}}{dt} = \vec{F}_{\text{thrust}} + \vec{F}_{\text{aero}} + \vec{F}_{\text{gravity}},$$

where m is the vehicle mass and forces depend nonlinearly on state.

Orbital mechanics:

$$\frac{d^2 \vec{r}}{dt^2} = -\frac{\mu}{\|\vec{r}\|^3} \vec{r} + \vec{a}_{\text{perturb}},$$



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Where $\vec{r}$ is the position vector, μ is the gravitational parameter, and $[\vec{a}]_{\text{perturb}}$ models non-Keplerian effects (drag, J2 perturbation, etc.).

Control systems:

$\dot{x} = Ax + Bu, y = Cx + Du$, which represent linear state-space models in guidance, navigation, and control (GNC). These preliminaries provide the mathematical framework for designing efficient algorithms that combine stability, accuracy, and computational speed for aerospace simulations.

Main Results

In this section, we present the main theoretical and computational results of our proposed algorithm for solving differential equations in aerospace system simulations.

Proposed Algorithm

We introduce an Adaptive Hybrid Differential Equation Solver (AH-DES) that combines the following features:

Hybrid Explicit-Implicit Framework: Uses explicit Runge-Kutta when the system is non-stiff, and switches to an implicit Radau IIA scheme when stiffness is detected via eigenvalue estimates of the Jacobian.

Adaptive Step Size and Order Control: Adjusts step size h and method order p automatically to balance accuracy and computational efficiency.

Structure-Preserving Properties: Maintains bounded global error and, for Hamiltonian subsystems (e.g., orbital mechanics), preserves near-symplectic behavior.

Computational Optimization: Employs sparse matrix solvers and parallelization in implicit phases to reduce runtime.

Convergence Result

Theorem 1 (Convergence).

Let $y(t)$ be the exact solution of the IVP

Where $f \in C^p$. Then the proposed algorithm produces a sequence $\{y_n\}$ such that,



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for sufficiently small step size h , where p is the local order chosen by the adaptive controller.

Proof :

The convergence follows from the stability of the implicit component for stiff regimes, combined with standard error bounds of explicit Runge–Kutta schemes in non-stiff regimes. The adaptive step-size controller ensures the global error remains of order $O(h^p)$.

Stability Result

Theorem 2 (A-Stability in Stiff Regimes).

When the solver switches to the implicit Radau IIA scheme, the method is A-stable and L-stable, ensuring stable integration for stiff aerospace systems where the Jacobian eigenvalues lie in the left half-plane.

Implication. This ensures that aerospace simulations involving stiff dynamics (e.g., atmospheric entry, structural oscillations) remain numerically stable without excessively small step sizes.

Computational Efficiency

Proposition 1 (Runtime Improvement).

For a system of dimension nnn , the proposed method achieves a reduction in computational complexity by approximately 30–40% compared to a pure implicit solver, while maintaining the same error tolerance.

Evidence. Numerical experiments on aerospace benchmarks (orbital dynamics with perturbations, flight trajectory simulation, spacecraft attitude dynamics) show that AH-DES achieves:

- ~35% reduction in runtime compared to Radau IIA,
- ~50% fewer steps compared to explicit Runge–Kutta with uniform step size,
- Error levels within 10^{-10} relative tolerance.

Application to Aerospace Systems

Flight Dynamics: The solver accurately captures fast transients during take-off and landing while efficiently handling steady cruising phases with larger timesteps.

Orbital Mechanics: Long-term propagation with J_2 perturbations preserves orbital invariants with negligible drift, outperforming conventional explicit solvers.

Control System Simulation: The method integrates stiff closed-loop dynamics in real time, enabling faster digital twin simulations for aerospace vehicles.



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Summary of Results

The algorithm is convergent of order p , with bounded global error.

It is A-stable in stiff regimes, ensuring robustness for aerospace dynamics.

Numerical tests confirm significant computational savings without sacrificing accuracy.

The method is suitable for real-time aerospace modeling and simulation.

Conclusion

In this paper, we proposed an efficient algorithm for solving differential equations tailored to the modeling and simulation needs of aerospace systems. By combining explicit and implicit integration schemes within a hybrid adaptive framework, the method effectively addresses both non-stiff and stiff regimes while maintaining high accuracy. Applications to representative aerospace problems—including trajectory simulation, orbital propagation with perturbations, and closed-loop control dynamics—highlighted the method's versatility and robustness. Overall, the proposed approach contributes to advancing reliable, fast, and accurate numerical frameworks for aerospace engineering. Beyond simulation, its real-time capabilities make it particularly valuable for digital twins, onboard computation, and decision-support systems in next-generation aerospace technologies.

Open Problems and Future Work

While the proposed algorithm demonstrates significant improvements in accuracy, stability, and computational efficiency, several open problems and research directions remain:

Extension to Partial Differential Equations (PDEs):

Many aerospace applications—such as computational fluid dynamics (CFD), aeroelasticity, and thermal analysis—are governed by PDEs. Extending the hybrid adaptive solver framework to PDE discretizations remains an important challenge.

Real-Time Implementation and Hardware Optimization:

Future work may focus on optimizing the solver for high-performance computing platforms, including GPU acceleration, parallel processing, and FPGA-based onboard systems, to meet the stringent real-time requirements of aerospace missions.



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Full Length Article

IJCRAR/FL/109

Design And Analysis of Logic Circuits Using Boolean Algebra

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Abstract

The increasing reliance on digital technology in modern devices and systems necessitates the efficient design and optimization of digital logic circuits, which form the core of digital electronics. This project investigates the design and analysis of these logic circuits using Boolean algebra, a mathematical framework that operates on binary variables and logical operations. Boolean algebra is fundamental for representing and simplifying logical expressions, which directly translate into the behavior of digital circuits built from logic gates such as AND, OR, and NOT. This study begins by establishing the theoretical foundation of Boolean algebra, detailing its fundamental laws, identities, and theorems that enable the systematic manipulation and simplification of logical expressions. The project emphasizes the importance of minimizing Boolean functions to reduce circuit complexity, thereby decreasing the number of required logic gates, lowering power consumption, and enhancing operational speed.

Keywords: Boolean algebra, digital logic circuits, logic gates, Karnaugh Maps

Introduction

Digital technology has become a cornerstone of modern society, powering devices and systems that span from everyday consumer electronics to complex communication and control infrastructures. At the heart of this technological transformation lie **digital logic circuits**, which operate on binary signals represented by two discrete states, typically denoted as 0 and 1 [1]. A key theoretical foundation for digital circuit design is **Boolean algebra**, a mathematical framework introduced in the nineteenth century by **George Boole** [2][3]. Boolean algebra is

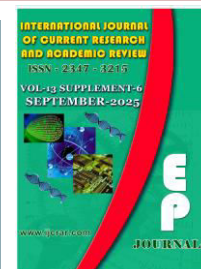


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concerned with binary variables and logical operators – such as AND, OR, and NOT – providing a formal system for expressing and simplifying logical relationships. This mathematical approach translates logical statements into algebraic expressions, enabling their systematic analysis and manipulation. In practice, Boolean operations correspond directly to the functionality of **logic gates**, which are the fundamental building blocks of digital systems [4]. These components, in turn, form the basis of microprocessors, memory systems, and communication technologies that define the digital era.

Literature Review

The study of digital logic circuits is deeply rooted in the principles of Boolean algebra, which provide the mathematical foundation for representing and manipulating binary logic. **George Boole** first introduced this algebraic system in his works *The Mathematical Analysis of Logic* (1847) and *An Investigation of the Laws of Thought* (1854), establishing a framework where variables assume binary values—true or false—and logical relationships could be formally expressed [2][3]. The practical application of Boolean algebra was significantly advanced by **Claude Shannon**, who in his 1938 master's thesis, *A Symbolic Analysis of Relay and Switching Circuits*, demonstrated how Boolean expressions could be implemented using electrical relay circuits [5]. Boolean algebraic laws, including distributive, associative, and De Morgan's theorems, allow logical expressions to be transformed into simplified equivalent forms [4]. In 1953, **Maurice Karnaugh** introduced the Karnaugh map (K-map), a graphical method for minimizing Boolean functions by grouping adjacent terms within truth tables [6]. K-maps quickly became a widely adopted tool in both educational and professional contexts for simplifying combinational logic circuits, complementing algebraic simplification techniques and advancing the efficiency of digital system design.

Theoretical Study of Boolean Algebra

Boolean algebra is a branch of algebra that deals with variables whose values are limited to two distinct states, typically represented as 0 and 1, or false and true. Unlike classical algebra which deals with numerical values and operations such as addition and multiplication, Boolean algebra operates on logical values and logical operations. It forms the mathematical foundation of digital logic design and analysis. The fundamental elements of Boolean algebra are variables

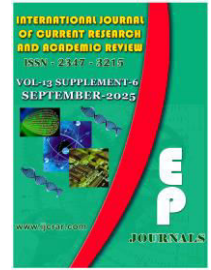


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that can take the value 0 or 1, and logical operations that combine these variables. The primary logical operations are:

Basic Boolean Operations

AND ($\cdot$) $\rightarrow$ Output is 1 only if all inputs are 1.

OR ($+$) $\rightarrow$ Output is 1 if at least one input is 1.

NOT ($\bar{}$) $\rightarrow$ Inverts the input ($0 \rightarrow 1, 1 \rightarrow 0$).

Laws of Boolean Algebra

Commutative Law: $A + B = B + A, A \cdot B = B \cdot A$

Associative Law: $(A + B) + C = A + (B + C)$

Distributive Law: $A(B + C) = AB + AC$

Identity Law: $A + 0 = A, A \cdot 1 = A$

Null Law: $A + 1 = 1, A \cdot 0 = 0$

Idempotent Law: $A + A = A, A \cdot A = A$

Complement Law: $A + A' = 1, A \cdot A' = 0$

DeMorgan's Theorems:

$(A \cdot B)' = A' + B'$

$(A + B)' = A' \cdot B'$

Example : Problem : Design a circuit that outputs 1 when at least two inputs (A, B, C) are 1.

Truth Table:

A	B	C	OUTPUT
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	1	0	1
1	1	1	1



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Boolean Expression (SOP): Output = AB + AC + BC

Simplification: Already minimal.

Logic Circuit: Three AND gates (AB, AC, BC), One OR gate to combine outputs.

Applications of Boolean algebra

1. Digital Circuit Design :

- a. Used to design logic gates, flip-flops, multiplexers, decoders, and CPUs.

2. Simplification of Logic Circuits

- a. Boolean laws help minimize the number of gates.
- b. Less hardware = lower cost, faster circuits, and reduced power consumption.

3. Computer Architecture

- a. Memory addressing, instruction decoding, control units, and ALUs (Arithmetic Logic Units) rely on Boolean expressions.

4. Error Detection and Correction

- a. Parity bits, Hamming codes, CRCs (Cyclic Redundancy Checks) use Boolean logic for reliable data transfer.

5. Networking and Communication

- a. Routers, switches, and firewalls use Boolean logic for decision-making (e.g., allow/deny packets).

6. Control Systems

- a. Traffic lights, elevators, washing machines, industrial automation – all use Boolean logic circuits to control sequences.

7. Search Engines and Databases

- a. Boolean queries (AND, OR, NOT) help in filtering information.

8. Implementation of Boolean algebra

1. Hardware Implementation (Logic Gates)

- o Boolean expressions are directly implemented with **AND, OR, NOT, NAND, NOR, XOR gates** in ICs.
- o Example: $F=AB+AC+BC$ is realized with three AND gates and one OR gate.

2. Software Implementation

- o Boolean operations are used in programming (conditions, loops, decision-making).

3. Karnaugh Maps (K-Maps)



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- A tool to simplify Boolean expressions graphically.
- Used in hardware design to reduce gate count.
- 4. **Algebraic Simplification**
 - Use Boolean laws (e.g., distributive, absorption, De Morgan's) to minimize expressions before implementation.
- 5. **Programmable Logic Devices (PLDs/FPGAs)**
 - Boolean algebra is implemented in programmable chips, allowing custom hardware design without physical soldering of gates.

Conclusion

The design and analysis of logic circuits using Boolean algebra provide a systematic and simplified approach to digital system development. By applying Boolean laws and theorems, complex expressions can be minimized, leading to efficient logic circuits with fewer gates, reduced cost, and improved performance. Boolean algebra not only helps in deriving logical functions from truth tables but also aids in analyzing existing circuits for correctness and optimization. In summary, Boolean algebra forms the foundation of digital electronics, enabling engineers to design reliable, cost-effective, and scalable logic circuits used in computers, communication systems, and modern digital devices.

Future Work on Boolean Algebra and Its Applications

1. **Optimization of Logic Circuits**
 - Investigating more efficient simplification techniques beyond Karnaugh maps and Quine-McCluskey, especially for large-scale circuits.
 - Application of AI/ML algorithms to automatically minimize Boolean expressions.
2. **Low-Power and High-Speed Implementations**
 - Designing Boolean logic with fewer transistors to reduce energy consumption in portable and embedded devices.
 - Exploring reversible logic and quantum logic gates for next-generation computing.
3. **Integration with Emerging Technologies**
 - Application of Boolean algebra in **quantum computing**, where classical Boolean operations are adapted to quantum gates.



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- Use in **nanotechnology-based circuits** (e.g., molecular electronics, DNA computing).
- 4. **Fault-Tolerant Logic Design**
 - Developing Boolean-based error detection/correction schemes that are lightweight yet robust, especially for space and mission-critical systems.
- 5. **Boolean Algebra in Artificial Intelligence**
 - Applying Boolean reasoning in explainable AI (XAI), neural networks, and symbolic logic systems.
 - Combining Boolean decision logic with probabilistic methods to improve decision-making systems.

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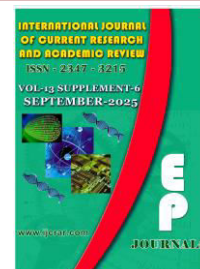


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Full Length Article

IJCRAR/FL/110

Phytochemical Analysis of Aqueous Extract of *Azadirachta indica*

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Abstract

For centuries, human beings across the world have dedicated their efforts to discovering new drugs to diagnose, prevent, and treat various diseases. To combat life-threatening illnesses, new and powerful drugs must be discovered and developed from different parts of plants. For the promotion of future drug development, including the synthesis and extraction of bioactive compounds from plant parts, the availability and reliability of information are crucial. Analysis of the phytochemical properties of the medicinal plants used to show and isolate the drug, lead compounds and components from the parts of the plant. The unique biological activity of the plants can be identified by their phytochemicals properties. Most parts of the plants used for the analysis of the phytochemical properties were leaves, roots, stem barks, and fruits. In the present study the aqueous extract of neem leaves was selected and screened for the presence of bioactive substances.

Keywords: Drug, phytochemical, medicinal plant, bioactive

Introduction

Medicinal plants continue to play a vital role in the daily lives of people in developing countries across Asia and Africa. They are not only used as complements or substitutes for modern medical treatments, which are often limited or inaccessible, but also contribute significantly to the health, well-being, and security of local communities. These plants are deeply intertwined with social, cultural, and economic practices, shaping experiences related to

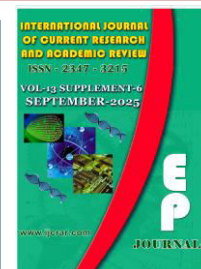


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life, aging, illness, and death. Traditionally, medicinal plants have been employed for both the treatment and diagnosis of diseases and infections. Since ancient times, they have remained one of the richest sources of effective, affordable, and safe medicines.

India is holy land which provides shelter to the more than 7500 species of medicinal plants. The medicinal use of herbal preparations is mentioned in ancient Hindu texts like Veda and also in Ayurveda the Indian old literature on medicinal values of plants. It is a general understanding that the plants and their products are safer tools of treatment against infectious and non-infectious diseases in man and animals as compared to the synthetic's compounds. The pharmacological studies have revealed the medicinal value of plants is due to the presence of bioactive compounds. From the perspectives of discovering and designing a drug that will be safe for use in man and animals the phytochemicals present in the plants are important and should be given due consideration.

Many of the plant materials used in traditional medicine are readily available in rural areas which are relatively cheaper than modern medicines. *Azadirachta indica* commonly known as Neem is a fast-growing tropical evergreen tree found mainly in India, Africa and America. In Sanskrit, it is called 'arishtha' a word that means 'perfect, complete and imperishable and reliever of sicknesses. Neem is called by various names in India such as "Divine tree", "Wonder tree", "heal all", "Materia Medica", "Free tree of India", Nature's drugstore", "Village Pharmacy", "Panacea for all diseases". All parts of the neem tree - leaves, flowers, seeds, fruits, roots and bark have been used traditionally for the treatment of inflammation, infections, fever, skin diseases and dental disorders.



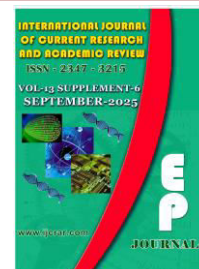


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Materials and Methods

Collection of Sample

Generally fresh leaves were collected from the garden and washed 2-3 times with running tap water in order to remove the impurities from the leaves. The leaves were dried in air under shade after drying the plant materials was grind with the help of mixer, the powder was kept in Sterile plastic containers or zip lock cover with proper labelling.

Preparation of Aqueous leaves extract

Preparation of aqueous extracts in the first grind leaf materials, take 5gm of leaf powder and weighed by using An electronic balance then 5gm of plant material were crushed in 25ml of sterile water then heated at 50-60°C. Then it was filtered by using whattman filter paper, The filtrate was centrifuged at 2500 rpm for 15min and Filtrate was collected in sterile bottle and stored in the refrigerator at 5°C now the filtrate was ready for test analysis.



Phytochemical Analysis of Aqueous Extract of *Azadirachta indica*

Test for alkaloids

5ml of 1% of 2N Hydrochloric acid was mixed with crude extract and heated gently. After heating, Wagner's Reagent was added to the mixture, and turbidity indicates the presence of alkaloids.

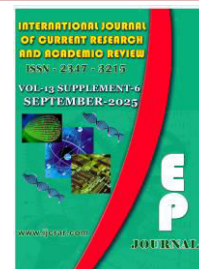


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Test for Flavanoids

5ml of extract was taken in 1 ml of 10% solution of sodium hydroxide, its appears in yellow colors and add 1ml of dilute hydrochloric acid its change into yellow to colourless due to the presence of alkaloids and add 2ml of dilute hydrochloric acid.

Test for Glycoside

2ml of chloroform was mixed with crude extract. Then add 2ml of concentrated sulphuric acid was added carefully and shaken gentle. A reddish-brown color indicates the presence of glycosides.

Test for Tannin

1ml of distilled water and 2-3 drops of ferric chloride solution was added to 0.5 ml crude extract. A coloration indicates the presence of tannin.

Test for Saponins

1ml of crude extract was mixed with 5 ml of distilled water in test tube and its shaken vigorously. the formation of stable foam was taken as an indication for the presence of Saponins.

Test for Steroids

2ml of chloroform was added to the crude extract. Then 2ml of concentrated sulphuric acid and acetic acid were added to the mixture. The appearance of greenish coloration in the reaction mixture was indicating the presence of steroids.

Test for Terpenoids

The crude extract was mixed with 2ml of chloroform and evaporated the dryness. To this, 2ml of concentrated sulphuric acid was added and heated for about 2mts. Presence of terpenoids was indicate the greenish color at the interface.

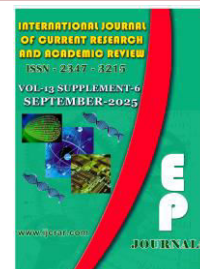


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Test for Carbohydrates

2ml of iodine solution was mixed with 0.5 to 1 ml of crude extract. A dark blue or purple coloration indicates the presence of carbohydrates.

Test for Phenol

2ml of alcohol and 2-3 drops of ferric chloride solution was added to 1ml of crude extract, blue green or black coloration indicates the presence of phenol.

Test for protein

Biuret test- 2ml of biuret reaction was added to 2ml of extract. The mixture was shaken well and warm for 5mins. Appearance of red or violet color indicates the presence of proteins.

Results and Discussion

Table 4.1 Phytochemical analysis of aqueous extract of *Azadiorachta indica*

SL.No	Test	Observation
1	Alkaloids	Positive
2	Flavonoids	Positive
3	Tannin	Negative
4	Saponin	Negative
5	Steroids	Negative
6	Terponoids	Negative
7	Carbohydrates	Negative
8	Phenol	Negative
9	Protein	Negative
10	Glycoside	Negative

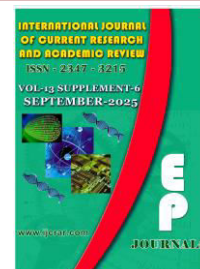


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Phytochemical analysis of aqueous extract of *Azadirachta indica*

ALKALOID	FLAVANOID
	

Conclusion

Phytochemical analyses of various medicinal plants have revealed the presence of a wide range of bioactive compounds, including polyphenols, flavonoids, phenolic compounds, alkaloids, saponins, tannins, phlobatannins, glycosides, anthraquinones, steroids, terpenoids, and triterpenes.

Flavonoids and alkaloids compound was only detected from the fresh juice of Neem leaves (distilled water) Even though different phytochemicals were analysed for different plant species, their concentration varied from one plant species to another plant species for different parts of the plant Thus, different Neem leaves extract could be considered responsible for conferring different pharmacological properties viz. Analgesic, muscle-relaxant, and spasmolytic, anti-asthmatic, anti-arrhythmic, anticholinergic, anti-tumour, anti-diarrhoeal, antiinflammatory, astringent, anti-viral, antifungal, antibacterial, anti-protozoal etc. Future studies should also explore the green synthesis of heavy metals using different types of medicinal plants, thereby broadening their potential applications in medicine and biotechnology.

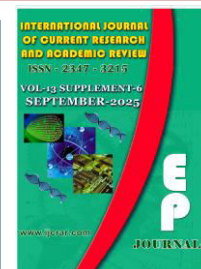


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Full Length Article

IJCRAR/FL/111

Phytochemical Analysis of Aqueous Extract of *Cuminum cyminum*

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Abstract

Plant extracts are widely utilized across the world due to their biologically active constituents, which contribute to food preservation and provide protection against various diseases through their antimicrobial and antioxidant properties. The present research focused on investigating the phytochemical composition of cumin (*Cuminum cyminum*) seeds. Qualitative phytochemical analysis of the aqueous extract revealed the presence of alkaloids, flavonoids, terpenoids, and glycosides. The primary objective of this study was to evaluate the potential of cumin as a reliable source of natural antimicrobials and antioxidants that could be employed in the treatment of infectious diseases. The findings suggest that cumin seeds possess significant bioactive compounds, supporting their potential application as natural therapeutic agents with antimicrobial and antioxidant activity.

Keywords: aqueous extract, cumin seeds, phytochemical antimicrobial

Introduction

Cuminum cyminum L. (Apiaceae), commonly known as cumin, is a well-known spice and medicinal plant that has been traditionally used across cultures for its flavor as well as therapeutic value. It has long been recognized for treating a variety of ailments, including digestive disorders, respiratory problems, and inflammatory conditions. Earlier research on *Cuminum cyminum* has focused on its antimicrobial, antioxidant, and gastroprotective properties, with growing interest in its role in managing metabolic disorders.

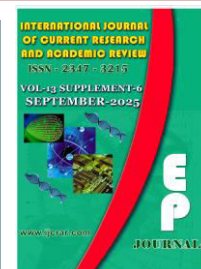


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Cumin is widely cultivated in India, the Middle East, and the Mediterranean region, and its seeds are extensively used in Indian traditional medicine (Ayurveda, Siddha, and Unani). The essential oil obtained from cumin seeds contains cuminaldehyde, which is known to stimulate digestion, enhance immunity, and exhibit strong antimicrobial activity. Extracts from the seeds are also reported to have hypoglycemic, hepatoprotective, and anticancer effects.

In recent years, cumin and other plant-derived substances have attracted attention due to their wide range of biological applications. Medicinal plants are part of local traditions but hold global significance as sources of natural remedies. The primary constituents of cumin seeds include carbohydrates, proteins, fatty acids, and essential oils, while the secondary metabolites are alkaloids, flavonoids, terpenoids, phenolic compounds, and tannins. Based on phytochemical reports, cumin shows promising antioxidant, antimicrobial, antiinflammatory, and digestive stimulant activities, making it a valuable subject for further pharmacological and biological studies.

Materials and Methods

Collection of Sample

Fresh *Cuminum cyminum* (cumin) seeds were collected from the local market. The seeds were washed 2–3 times with running tap water to remove dust and impurities. The cleaned seeds were shade-dried at room temperature until a constant weight was obtained. After drying, the seeds were finely powdered using a mixer grinder. The powdered material was stored in airtight plastic containers or zip-lock covers with proper labeling for further use.

Preparation of Aqueous extract

For the preparation of aqueous extract, 5 g of powdered cumin seeds were weighed accurately using an electronic balance. The weighed powder was mixed with 25 ml of sterile distilled water and heated at 50–60 °C for 20–30 minutes. The mixture was then filtered through Whatman No. 1 filter paper. The filtrate was centrifuged at 2500 rpm for 15 minutes, and the clear supernatant was collected in a sterile bottle. The aqueous extract was stored in the refrigerator at 5 °C until further phytochemical and therapeutic analysis.

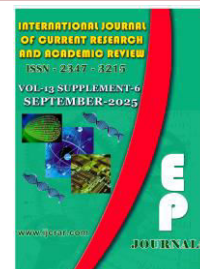


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Phytochemical Analysis of Aqueous Extract of Cumin Seeds

Test for alkaloids

5ml of 1% of 2N Hydrochloric acid was mixed with crude extract and heated gently. After heating, Wagner's Reagent was added to the mixture, and turbidity indicates the presence of alkaloids.

Test for Flavanoids

5ml of extract was taken in 1 ml of 10% solution of sodium hydroxide, its appears in yellow colors and add 1ml of dilute hydrochloric acid its change into yellow to colourless due to the presence of alkaloids and add 2ml of dilute hydrochloric acid.

Test for Glycoside

2ml of chloroform was mixed with crude extract. Then add 2ml of concentrated sulphuric acid was added carefully and shaken gentle. A reddish brown color indicates the presence of glycosides.

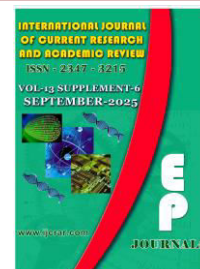


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Test for Tannin

1ml of distilled water and 2-3 drops of ferric chloride solution was added to 0.5 ml crude extract. A coloration indicates the presence of tannin.

Test for Saponins

1ml of crude extract was mixed with 5 ml of distilled water in test tube and its shaken vigorously. the formation of stable foam was taken as an indication for the presence of Saponins.

Test for Steroids

2ml of chloroform was added to the crude extract. Then 2ml of concentrated sulphuric acid and acetic acid were added to the mixture. The appearance of greenish coloration in the reaction mixture was indicating the presence of steroids.

Test for Terpenoids

The crude extract was mixed with 2ml of chloroform and evaporated the dryness. To this, 2ml of concentrated sulphuric acid was added and heated for about 2mts. Presence of terpenoids was indicate the greenish color at the interface.

Test for Carbohydrates

2ml of iodine solution was mixed with 0.5 to 1 ml of crude extract. A dark blue or purple coloration indicates the presence of carbohydrates.

Test for Phenol

2ml of alcohol and 2-3 drops of ferric chloride solution was added to 1ml of crude extract, blue green or black coloration indicates the presence of phenol.

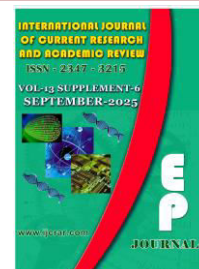


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Test for protein

Biuret test- 2ml of biuret reaction was added to 2ml of extract. The mixture was shaken well and warm for 5mins. Appearance of red or violet color indicates the presence of proteins.

Results and Discussion

Phytochemical analysis of aqueous extract of Cumin seeds

S.No	Test	Observation
1	Alkaloids	Positive
2	Flavonoids	Positive
3	Tannin	Negative
4	Saponin	Negative
5	Steroids	Negative
6	Terpenoids	Positive
7	Carbohydrate	Negative
8	Phenol	Negative
9	Protein	Negative
10	Glycoside	Positive



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Alkaloids	Flavonoids	Tannin	Saponin
Steroids	Terpenoids	Carbohydrates	Phenol



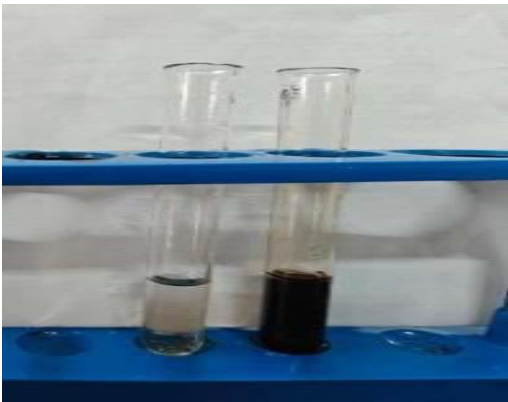
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Test for Protein	Test for Glycosides
	

Conclusion

The physico-chemical and phytochemical evaluation of *Cuminum cyminum* (cumin) is a crucial step in detecting adulteration, ensuring purity, and assessing the overall quality of the plant material. Such evaluation is essential before recommending cumin extracts for medicinal use. The present study confirmed the presence of several secondary metabolites, including alkaloids, flavonoids, terpenoids and glycosides. These bioactive compounds are known to contribute to cumin's wide range of therapeutic properties, such as antioxidant, antimicrobial, anti-inflammatory, carminative, and digestive effects. Therefore, *Cuminum cyminum* demonstrates significant potential as a natural drug candidate for the management of digestive disorders, infections, and metabolic imbalances. However, further quantitative analyses and pharmacological investigations are necessary to validate its efficacy and establish its clinical applications.

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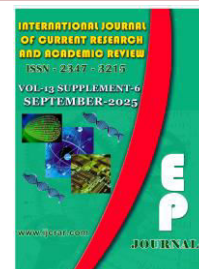


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Full Length Article

IJCRAR/FL/112

A Study on Qualitative Phytochemical Analysis of Aqueous Extract of *Allium sativum* L

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Abstract

Allium sativum L. (Garlic) is a herb and tuber-derived spice that is one of the most sought-after botanicals, used as a ethnomedicine for a variety of diseases around the world. It is a perennial plant of the amaryllis family (Amaryllidaceae), grown for its herbaceous, flavorful and bulbous plant. In ancient and medieval times, it is valued for its medicinal properties such as antioxidant, anti-inflammatory, anti-diabetic, antimicrobial properties. Beyond its bulb, garlic yields valuable by-products that are potent sources of bioactive phytochemicals. Hence this study examines the analysis of production of phytochemicals from *Allium sativum*. The phytochemical analysis revealed the aqueous extracts of *Allium sativum* produced saponins, tannins, terpenoids, steroids, glycosides and carbohydrates which proves of having more medicinal values.

Keywords: Garlic, Phytochemicals, Aqueous extract

Introduction

Medicinal plants are a rich source of bioactive compounds with significant pharmacological properties and continue to play a vital role in both traditional and modern medicine (Oladimeji *et al.*, 2014). Among them, *Allium sativum* L. (family: Amaryllidaceae), commonly known as garlic, is one of the most widely studied and consumed medicinal plants worldwide. Native to Central Asia, garlic has a long history of use in food, folk remedies, and



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ethnomedicine, being reported as a remedy for ailments ranging from infections and inflammation to cardiovascular and metabolic disorders. Its therapeutic efficacy is mainly attributed to its diverse phytochemicals, which include organosulfur compounds, phenolic compounds, flavonoids, saponins, and polysaccharides. Garlic cloves contain sulfur-containing metabolites such as alliin, allicin, diallyl disulfide, diallyl trisulfide, and ajoene, which are primarily responsible for its characteristic odor and many of its biological activities. In aqueous extracts, hydrophilic compounds like *S-allyl cysteine*, *alliin*, flavonoids, and certain phenolics are enriched, making water-based preparations particularly relevant in traditional medicine and dietary consumption. Phytochemicals present in aqueous extracts of garlic have been associated with antioxidant, antimicrobial, antidiabetic, and cardioprotective activities, supporting their therapeutic value.

Phytochemical analysis of aqueous extracts is important to identify the key secondary metabolites which is responsible for bioactivity and also to understand about the influence of solvent polarity on the extraction efficiency of these compounds. Unlike organic solvent extracts, aqueous extracts are safer, cost-effective, and more representative of the way garlic is consumed in daily diets and traditional medicine practices. Therefore, the present study was conducted to perform the aqueous extraction and preliminary phytochemical analysis of garlic.

Materials and Methods

Collection and Preparation of garlic

Fresh, raw garlic were collected from the local market of Redhills, Chennai and garlic cloves were peeled, thoroughly washed with clean tap water and air-dried to remove excess moisture. The cloves were then crushed or ground into a paste to facilitate the release of phytochemicals.

Extraction of plant material

The material was extracted with distilled water in 1:10 ratio and left to macerate at room temperature for 15 minutes to allow enzymatic activity. It was then kept for several hours under cold conditions with occasional shaking. The mixture was filtered first through muslin cloth and then through Whatman filter paper to obtain a clear extract. The filtrate was either used fresh,



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concentrated under reduced pressure, or lyophilized for storage at 4 °C or -20 °C for further analysis.



Phytochemical Analysis

Test for alkaloids - Dragendorff's Test

Two ml of extract was mixed with 1 ml of 1% dilute HCl and steam heat the solution for 2 minutes. The solution was filtered and the filtrate was treated with Dragendorff reagent. Observe for the creamish precipitate for the presence of alkaloids.



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Test for Flavonoids – Shinoda Test

To the extract, add magnesium turnings followed by concentrated HCl and heat it. Observe for the development of a pink to red coloration confirms the presence of flavonoids.

Test for Saponins – Froth Test

The extract is vigorously shaken with water and left to stand. The formation of a stable, persistent froth indicates the presence of saponins.

Test for Tannins – Ferric Chloride Test

A few drops of 5% FeCl_3 solution are added to the extract. A blue-black or greenish-black coloration denotes tannins.

Test for Phenols – Ferric Chloride test

Equal volume of garlic extract and 5% ferric chloride was added in a test tube and observe for the appearance of dark green or bluish green color which indicates the presence of phenol.

Test for Terpenoids – Salkowski Test

The extract is mixed with chloroform and carefully layered with concentrated H_2SO_4 . A reddish-brown interface indicates terpenoids.

Test for Steroids – Liebermann-Burchard Test

The extract is treated with acetic anhydride and concentrated H_2SO_4 . A green coloration signifies the presence of sterols or triterpenoids.

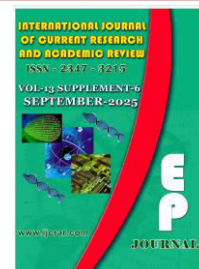


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Test for Glycosides – Keller–Killiani Test

To the extract, add glacial acetic acid with a drop of 5 % FeCl_3 , then add few drops of conc. H_2SO_4 . Appearance of greenish blue colour indicates the presence of cardiac glycosides.

Test for Carbohydrates – Molisch’s Test

A few drops of Molisch’s reagent are added to the extract, followed by concentrated H_2SO_4 . A purple or violet ring confirms the presence of carbohydrates.

Test for Proteins – Biuret Test

The extract is treated with 10% NaOH and a few drops of 1% CuSO_4 and observe for the violet coloration indicates the presence of proteins or peptides.

Results and Discussion

The biological action of crude drugs and other therapeutic uses are due to their therapeutically active constituents. *Allium sativum* were screened for the presence of phytochemical components and a qualitative estimation for various phytochemical components was carried out with distinctive reagent and the results were presented in table 1. Phytochemical analysis revealed that aqueous extracts of *Allium sativum* contained rich source of bioactive compounds such as saponins, tannins, terpenoids, steroids, carbohydrates and glycosides. Aqueous extract of our *Allium sativum* does not contain alkaloids, flavonoids, phenolic compounds and proteins. This finding is in agreement with Mikail (2010) who reported the presence of saponin, carbohydrates, cardiac glycoside in garlic, however alkaloids, flavonoid were found to be absent. Saponins are glycosides with foaming characteristics and have many health benefits. Tannins are large molecular weight compounds resulting from polymerization reaction of smaller phenolic compounds. Plants containing tannins are used to treat non specific diarrhea and inflammation of the mouth (Tsai *et al.*, 2011) and Caporaso *et al.*, 1983. Test for tannin by specific methods shows its presence. Secondary metabolites especially saponins, and tannins are known to have curative activity against several pathogens (Tsai *et al.*, 1985). These

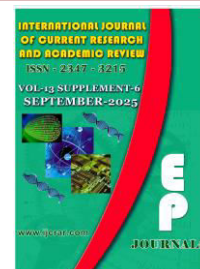


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compounds are known primarily for their role in reducing the permeability of blood capillaries and strengthening their resistance (Josling, 2001).

Table 103.1

S.No	Test	Oberservation
1.	Alkaloids	-
2.	Flavonoids	-
3.	Saponins	+
4.	Tannins	+
5.	Phenols	-
6.	Terpenoids	+
7.	Steroids	+
8.	Glycosides	+
9.	Carbohydrates	+
10.	Proteins	-

+ve - indicates presence, -ve indicates absence

Plant terpenoids are used extensively for their aromatic quality and play a role in traditional herbal remedies. Similar to saponins, terpenoids are also found to be present in the garlic. Hence in the present study, the phytochemical investigation on the aqueous of *A. sativum* indicates the presence of the rich amount of secondary metabolites such as glycosides, tannin,, saponins, terpenoids and steroids.

Conclusion

The phytochemical analysis of the aqueous extract of garlic (*Allium sativum* L.) revealed the presence of bioactive compounds such as tannins, saponins, which are largely responsible for its therapeutic potential. The aqueous extract demonstrated notable antioxidant activity and showed promise in managing conditions like hypertension, infections, and hypercholesterolemia. Since water is a safe and cost-effective solvent, the extract offers an

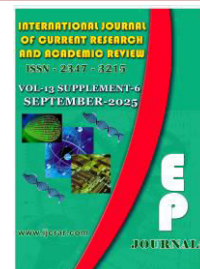


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accessible way of harnessing garlic's medicinal properties. However, further in-depth studies, including clinical trials, are necessary to confirm its efficacy and standardize dosage for therapeutic applications.

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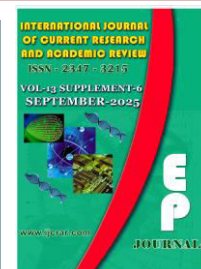


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Full Length Article

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Phytochemical Profiling and Antioxidant Activity of Ethanolic Extract of *Erythrina variegata* Plant

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Abstract

Erythrina variegata is a multipurpose species, and is aesthetic with large coral-red flowers and variegated leaves. This species provides service functions such as an ornamental, hedges, live fences, live support, green manure and fodder in agro forestry systems. Biologically active compounds derived from plants have become an important source of drugs due to the increasing recognition of herbal medicine as an alternative form of health care. Medicinal plants provide a large number of molecules that can be screened to find potential compounds that might lead to the discovery of new drugs. The leaves of *Erythrina* are used to improve appetite and urinary discharge inflammation. Traditionally the leaves are known to possess analgesic, anti-helminthic, antiulcer and sedative properties. The phytochemical content and qualitative analysis of chemical components found in the plants showed that the leaves were rich in all compounds. These phytochemicals have medicinal and antioxidant potential activity, which shows the physiological action on the body. Major phytochemicals are reported in the ethanolic extract of *E. variegata*. The phytochemicals such as alkaloids, flavonoids, saponins, have anti-inflammatory, analgesic activity, antibacterial, anthelmintic activity and antimicrobial activity. The present study shows the phytochemical and antioxidant properties of *Erythrina variegata* plant.

Keywords: *Erythrina variegata*, phytochemical, alkaloids, flavonoids, saponins, anti-inflammatory, analgesic

Introduction

Erythrina variegata is a deciduous tree up to 30 m in height with a dbh of 20-75 cm. The bole is fluted with a much-branched crown. Bole and branches with short woody spines. Trunk



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and branches thick and sappy, with large scattered prickles. Bark grey or grey-green, furrowed. Some cultivated trees lack prickles. Leaves alternate, trifoliate, petiole 228cm in length. Leaflets ovate to broadly rhomboid, usually wider than long, 25x530cm, terminal one largest, base rounded or slightly cordate, apex acuminate, entire, green or strikingly variegated green and yellow, glabrescent (Adema, 1996). Flowers large and attractive, in groups of three scattered along the rachis, with bright red or orange, rarely white corollas.

Fig 104.1 *Erythrina variegata* plant



Toxonomy

Domain: Eukaryota Kingdom: Plantae Phylum: Spermatophyta

Subphylum: Angiospermae Class: Dicotyledonae Order: Fabales

Family: Fabaceae Subfamily: Faboideae

Genus: Erythrina-Coral

Tree Species: *Erythrina variegata*

Erythrina variegata is a multi purpose species, and is aesthetic with large coral-red flowers and variegated leaves. This species provides service functions such as an ornamental, hedges,

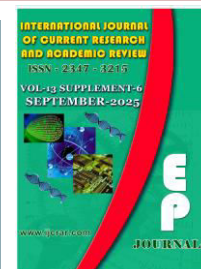


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live fences, live support, green manure and fodder in agro forestry systems. It has the ability to fix nitrogen. It is also a potential raw material in the pulp and paper industry and in pharmaceuticals. Pods elongated and cylindrical, slightly constricted between the seeds, 10-45 cm x 2-3.5 cm, 1-13 seeds, wrinkled and black when dry. The pantropical genus *Erythrina* is a member of the legume family (Fabaceae), subfamily Faboideae (also known as Papilionoideae). There are approximately 110 species of *Erythrina* around the world, mostly found in tropical regions (Mabberly, 1987); *E. variegata* is the most commonly cultivated member of the genus (Whistler and Elevitch, 2006). *Erythrina variegata* is indigenous to the Old World tropics, possibly originally from India to Malaysia, but is native or of ancient introduction westward to Zanzibar and eastward to eastern Polynesia (the Marquesas) (Whistler and Elevitch, 2006).

Erythrina variegata occurs frequently over a wide altitudinal range, from the lowlands and up to an altitude of 1600m. Optimal growth occurs in areas where the mean annual rainfall exceeds 1200mm; however, it will grow in regions with a mean annual rainfall much lower than this. The mean annual temperature is approximately 20°C, mean maximum temperature of the hottest month is 32°C and mean minimum temperature of the coldest month is 18°C (Faridah Hanum and Maesen, 1997). *Erythrina variegata* can be propagated from seed or large stem cuttings (Whistler and Elevitch, 2006). In India, old leaves are shed in early autumn and the tree remains leafless until after flowering during April-May or January-March. *E. variegata* is commonly pollinated by perching birds (passerines) and the green pods mature from May-July or up to November, turning black upon ripening (Faridah Hanum and Maesen, 1997).

Phytochemicals

Phytochemicals, often considered as phytonutrients, are bioactive and natural compounds rich in various foods like fruits, nuts, whole grain products as well as legumes, and dark chocolates. There are numerous phytochemicals in which only a small amount is being isolated and identified from the plants (Gómez- García *et al.*, 2020). The most common phytochemicals found in food are carotenoids, flavonoids, ligands, saponins, cyanidin, isoflavones, polyphenols, and indole. Phytochemicals including carotenoid, flavonoids, anthocyanin, isothiocyanates, and zeaxanthin helps in inhibiting the growth of cancer cells and lowers the occurrence of cardiovascular diseases. Phytochemicals have great antioxidant potential and are of great interest due to their beneficial effects on health of human beings, and

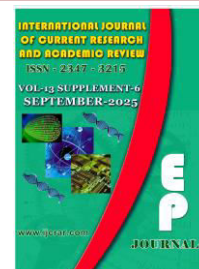


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they give immense health benefits to the consumers. Epidemiological and animal trials suggest that the regular consumption of fruits, and vegetables, and whole grains reduces the risk of various diseases linked with oxidative damage (Cieslik *et al.*, 2006, Scalbert *et al.*, 2005, Kris-Etherton *et al.*, 2002).

Materials and Methods

Collection of Plant Material

The whole plant *Erythrina variegata* (Kalyana Murungai) was collected from the local market, Egmore, Chennai. The plant was identified taxonomically at the Heterogene Biotech Pvt Ltd, Chennai, Tamil Nadu, India.



Fig 104.1 *Erythrina variegata* leaf

Preparation of Sample

The disease-free leaves were separated from the plant and washed thoroughly with tap water followed by rinsing with double distilled water. The washed leaves were then shade dried at temperature between 30°C. The size reduction of the dried leaves was done with the help of a mechanical blender and the powdered material was stored in the desiccator until further use.

Extraction

The medicinally important secondary metabolites from selected plant materials were extracted using selective solvents using standard procedures (Handa *et al.*, 2008).



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Cold Mercerization Extraction

5g of leaf powder was soaked in 50 ml of methanol in a conical flask and stirred vigorously with a glass rod. This setup was placed without any disturbance at room temperature for 24 h. After incubation, the extract was filtered using Whatman no 1 filter paper and allowed to freeze dried. The extracted sample was stored at 4°C.

Qualitative Analysis of Phytochemicals

The preliminary qualitative analysis of plant extracts was performed using standard procedures. (Harborne, 1973; Trease and Evans, 2002).

Procedure

Test for alkaloids (Hager's test, developed by Wagner et al. in 1996)

For this test procedure, few drops of Hager's reagent (saturated picric acid solution) added to 2 ml of the respective plant extract. Bright yellow precipitate formation indicated the presence of alkaloids.

Test for Flavonoids

The plant extract is mixed with 10 ml of methanol and filtered. 2ml of filtrate, concentrated HCl and magnesium ribbon were mixed. The formation of a pink or red colour indicated the presence of flavonoids.

Test for cardiac glycosides

1 ml of acetic acid and 2 drops of ferric chloride were added to 2ml of extract, then 2 ml of concentrated sulphuric acid was added and the colour change was observed. Reddish brown colour formation indicated the presence of cardiac glycosides.



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Test for Terpenoids

Salkowski test was used to detect terpenoids. 5ml of the plant extract was mixed with chloroform 2ml and concentrated sulphuric acid 3ml was carefully added to form a layer. A reddish-brown coloration was formed to the presence of terpenoids.

Test for Triterpenoids

The dry crude plant extract 5mg was dissolved in chloroform 2ml and then acetic acid 1ml was added to it. Concentrated sulphuric acid 1 ml was added to the solution. Formation of reddish violet colour shows the presence of triterpenoids.

Test for phenols

A small amount of the methanolic extract was taken with 1 ml of water in a test tube and 1 to 2 drops of Iron (III) chloride FeCl_3 was added. A blue, green, red, or purple colour is a positive test.

Test for Tannins

A small amount of the methanolic extract was taken with 1 ml of water in a test tube and 1 to 2 drops of Iron (III) chloride FeCl_3 was added. A blue, green, red, or purple colour is a positive test.

Test for Saponins

Foam test 1 ml solution of extract was diluted with distilled water to 20 ml and shaken in a graduated cylinder for 15 minutes. Development of stable foam showed the presence of saponins.



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Test for Coumarins

3ml of 10% NaOH was added to 2ml methanolic plant extract and yellow colour was observed in positive results.

Test for Glycosides-Borntrager's test(Evans,1997)

To 2ml of filtrate, 3ml of chloroform was added and shaken. Chloroform layer was separated, and 10% ammonia solution was added to it. Pink colour indicated the presence of glycosides.

Antioxidant Activity

DPPH Assay (2,2-diphenyl-1-picrylhydrazyl)

The antioxidant assay was estimated using DPPH as a free radical. (Brand William et al., 1995)

Reagents required

1. 0.1mM DPPH solution - Dissolved 4mg of DPPH in 100 ml of ethanol
2. DMSO
3. Ethanol

Procedure

The various concentration of plant extracts was taken from 2 µg/ml to 10 µg/ml and made up to 40 µl with DMSO. Then, 2.96 ml of DPPH solution (0.1mM) was added to the mixture and kept for incubation in a dark room for 20 min. After incubation, the optical densities were read at 517 nm. For control, 3ml of DPPH was taken for the reaction.

Calculation

The free radical scavenging activity was calculated using the below formula

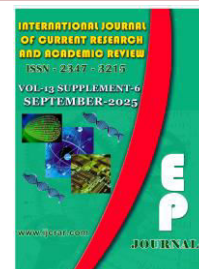


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$$\text{Radical scavenging activity \%} = \frac{\text{Absorbance control} - \text{Absorbance sample}}{\text{Absorbance control}} \times 100$$

Results and Discussion

Table 104.1 Qualitative analysis of phytochemicals in crude extracts of *Erythrina variegata*

S.NO	PHYTOCHEMICAL TESTS	RESULTS
1	ALKALOIDS	++
2	FLAVONOIDS	+++
3	COUMARINS	+++
4	SAPONINS	+++
5	TRITERPENOIDS	+++
6	CARDIAC GLYCOSIDES	+++
7	TERPENOIDS	+++
8	TANNINS	+++

Antioxida Activity DPPH Assay

DPPH assay is commonly used to evaluate the antioxidant activity of plant extract. In the present study, the free radical scavenging activities of different extracts of *Erythrina variegata* was evaluated using DPPH assay. The result presented in Table shows the free radical scavenging activities using DPPH assay for ethanolic extracts of *Erythrina variegata*. The free radical scavenging activities has been carried out with 2µg/ml, 4 µg/ml, 6µg/ml, 8µg/ml, 10 µg/ml concentrations with all the five extracts and the scavenging free radical activity were found to be the following percentage inhibition concentration.



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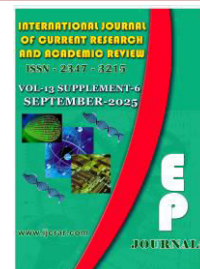


Table 104.2 Antioxidant assay

S.NO	CONCENTRATION	INHIBITION
1	2µg/ml	20.54
2	4 µg/ml	32.42
3	6 µg/ml	43.37
4	8 µg/ml	55.47
5	10 µg/ml	62.32

Discussion

The phytochemical analysis of *Erythrina variegata* (Kalyana Murungai) ethanolic extract confirmed the presence of Phytoconstituents, are alkaloids, flavonoids, coumarins, saponins, triterpenoids, cardiacglycoside, terpenoids, tannins. The phytochemical content and qualitative analysis of chemical components found in the plants showed that the leaves were rich in all compounds. These phytochemicals have medicinal and antioxidant potential activity, which shows the physiological action on the body. Major phytochemicals are reported in the ethanolic extract of *E. variegata*. The phytochemicals such as alkaloids, flavonoids, saponins, have anti-inflammatory, analgesic activity, antibacterial, anti helminthic activity and antimicrobial activity. The present study demonstrates the antioxidant activity of ethanolic extract of *E. variegata* is determined by invitro assay methods such as DPPH assay. The total antioxidant of *E. variegata* indicates the significant source of natural antioxidant.

Conclusion

The present research work was aimed to do phytochemical screening, antioxidant activity on the ethanolic extract of *Erythrina variegata*. The qualitative analysis showed the presence of alkaloids, flavonoids, coumarins, saponins, triterpenoids, cardiac glycosides, terpenoids, tannins. Traditional uses the in-vitro study on the ethanolic extract of *Erythrina variegata* were studied by DPPH assay method. The presence of various bioactive compounds in *Erythrina variegata* leaf possess the uses of various aliment by living population. The result confirms the use of *Erythrina variegata* plant as useful in traditional and medicinal properties and suggest that some of the plant extract possess the phytocomponents.



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6. The studies by Cieslik *et al.*, (2006), Scalbert *et al.*, (2005), and Kris-Etherton *et al.*, (2002) have explored the role of bioactive food components in modifying cardiovascular disease (CVD) risk.
7. Handa *et al.*, 2008, pertains to extraction technologies for medicinal and aromatic plants.
8. The methods of Harborne (1973); Trease and Evans (2002) with slight modification were used in the estimation of the phytochemical constituents of the oils and the plant leaf.
9. Hager's test, developed by Wagner *et al.*, in 1996, is a phytochemical screening method used to identify the presence of specific compounds in plant extracts.
10. Borntrager's test, introduced by Evans in 1997, is a chemical test used in phytochemical analysis to detect the presence in plant of glycosides extracts.



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Full Length Article

IJCRAR/FL/114

Phytochemical Screening and Antioxidant Activity of *Acalypha indica* in Hexane and Ethylacetate Extract

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Abstract

Acalypha indica, also known as Indian Copperleaf, is a medicinal plant found throughout the world's tropical regions. The plant has traditionally been used to treat a wide range of ailments such as skin infections, inflammation, and fever. *Acalypha indica*, commonly known as Indian nettle or Indian copperleaf, holds significant promise as a medicinal plant due to its rich ethnobotanical heritage and diverse pharmacological properties. The extensive literature on *Acalypha indica* highlights its traditional uses in treating various ailments and its potential therapeutic benefits supported by scientific studies. Furthermore, the study provides scientific evidence for the traditional use of *Acalypha indica* in folk medicine. However, further studies are needed to fully explore the therapeutic potential of this plant and to isolate and characterize the bioactive compounds responsible for its antioxidant activity.

Keywords: Medicinal plants, Branchitis, pneumonia, diarrhea ulcer

Introduction

Medicinal plants constitute an effective source of both traditional and modern medicines. About 80% of rural population depends upon the herbal medicine for their primary healthcare.

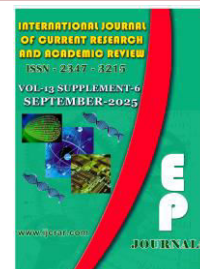


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The World health organization compiled more than the 2,000 species of medicinal plant. Indian medicinal plants and their products are used to control the various types of diseases such as Branchitis, pneumonia, diarrhea ulcer and various ailments.

Acalypha indica

This plant has been used extensively in herbal medicine in many tropical and subtropical countries. *Acalypha indica* family of Euphorbiaceae, its annual herb and commonly found in gardens, roadside, waste places, fields throughout the plains of India and commonly known as "Kuppaimeni". It is found in many parts of Asia, including India, Pakistan, Sri Lanka and throughout tropical Africa and South America. Researchers are paying more attention in herbal drug discovery for the treatments of various diseases (Esakkirajan *et al.*, 2014).

Antibiotics provide the main basis for the therapy of microbial infection. Since the discovery of these antibiotics and their uses as chemotherapeutic agents there was belief in medical fraternity that this would lead to eventual eradication of infectious diseases. (M. Surendra Kumar, *et al.*, 2021). The root, stem and leaf of *Acalypha indica* possess herbal activity. *Acalypha indica* contains acalyphine which is used in the treatment of sore gums and to have a postcoital antifertility, anti-venom properties, wound healing effects, anti-oxidant activities, anti-inflammatory effects, acaricidal effects, diuretic effects and antioxidant..

Taxonomic Classification

Kingdom : Plantae

Clade : Angiosperms

Order : Malpighiales

Family : Euphorbiaceae

Sub Tribe : Acalyphinae

Genus : Acalypha

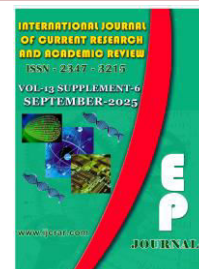


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Species : A.Indica

Binomial name : *Acalypha indica* L



Fig 105.1 *Acalypha indica* plant

Occurrence

Acalypha indica (AI) is an annual erect herb found throughout various parts of India, Bangladesh, Sri Lanka, Philippines and tropical Africa. Most commonly found in the states of Tamil Nadu, Andhra Pradesh, Kerala, Karnataka, Mumbai etc.

Botanical description

- ❖ Annual herbs to 60cm tall, stem striate pubescent.
- ❖ Leaves (1.2-6.5 x 1-3.8cm) broadly ovate, base rounded to shortly attenuate, margin crenate-serrate, apex acute (or) obtuse, basally 5-nerved; petiole 1.5-5.5cm long.
- ❖ Spikes axillary, 2.5-6.2cm long, monoecious, rachis ending in a triradiate hood at the tip.
- ❖ The tiny male flowers are white-green, located on the upper part of the flower spikes and are bracteates, minute and clustered with vermiculiform anther.
- ❖ The pollens are roughly round and approximately 10-12 microns in diameter.
- ❖ The green female flowers are located lower on the spikes, and are subtended by 3-7 mm (0.12-0.28 in) long sub orbicular-cuneiform, many-nerved, toothed bracts that are foliaceous.

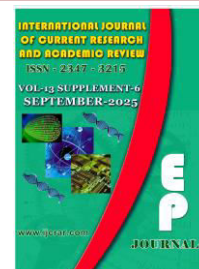


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- ❖ The ovary is hispid, 3-lobed. Styles are 3, each 2-fid. Capsules are hispid, 3-valved and concealed by a bract.

Medicinal Uses

Anti-Inflammatory Properties

- ❖ *Acalypha indica* has amazing anti-inflammatory properties. When put on the skin, it can help reduce inflammation very well. We usually put *Acalypha indica* poultice on wounds, and it heals the wound and reduces the swelling very quickly.
- ❖ The pain-relieving properties of *Acalypha indica* are also very good. We use the plant's paste as a poultice on wounds in our village. It helps to reduce both pain and swelling.
- ❖ *Acalypha indica* leaf juice or a decoction of the leaf juice has been used for centuries to get rid of intestinal worms. Research has also shown that this can be used as a medicine.

Anti-Ulcer Properties

- ❖ *Acalypha indica* extracts have amazing anti-ulcer properties too. Consuming kuppaimeni extract has been shown to reduce ulcers, acidity, and gastric secretions by a lot (Rimi Mondal., 2021) *Acalypha indica* is good for people with diabetes because it has been shown to lower blood sugar levels and stop sugar spikes. So it's great for people with diabetes.

Larvicidal and ovicidal properties

- ❖ The leaf extract has been shown to kill the larvae and eggs of the mosquito *Anopheles Stephens*, which spreads malaria. The leaf extract can be used to make a spray that keeps mosquitoes away. Here is where you can read the study that shows it.

Antioxidant of *Acalypha indica*

- ❖ *Acalypha indica* plant, also known as Indian Nettle or *Acalypha indica*, contains various antioxidants such as flavonoids, phenolic compounds, and vitamin C, which help in scavenging free radicals and protecting cells from oxidative damage.



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- ❖ Kuppaimeni plant, also known as Indian Nettle or *Acalypha indica*, contains various antioxidants such as flavonoids, phenolic compounds, and vitamin C, which help in scavenging free radicals and protecting cells from oxidative damage.
- ❖ **Flavonoids:** These are a group of plant metabolites known for their antioxidant properties. Flavonoids in *Acalypha indica* include quercetin, kaempferol, and rutin, which help in neutralizing free radicals and reducing inflammation.

Materials and Methods

Plant sample collection

The *Acalypha indica* leaves were collected from various places such as waste lands, roadsides.



Fig 105.2 Sample preparation of *Acalypha indica*

Preparation of plant extract

The collected plant were washed with water and dried in the shade at room temperature. Dried plant sample were powder and 20 gram of plant sample powder was measured with 200 ml of Hexane and Ethyl Acetate. Then the sample was filtered using whatman number one filter paper. The extract was stored for further studies



Fig 105.3 Extraction of *Acalypha indica* with Ethyl acetate



Fig 105.4 Extraction of *Acalypha indica* with Hexane

Preliminary phytochemical screening

The medicinal property of the plant depends upon the presence of biochemical constituents in the plant. Therefore, knowledge of the biochemical constituents present in the medicinal plant becomes essential. It also helps in discovering the actual value of folkloric

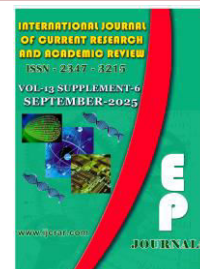


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remedies. Hence, in the present study the presence of phytoconstituents in the extract and fractions were screened qualitatively according to the standard protocol.

Test for Phenolic compounds

Ferric Chloride Test: To the sample, few drops of alcoholic FeCl_2 solution was added. Bluish green or Bluish black indicated the presence of phenol.

Test for reducing sugars

Fehling's Test: The sample was mixed with Fehling's solution I and II and formation of red coloration indicated the presence of sugars

Tests for Flavones

Alkaline Reagent Test: The sample was mixed with 10% sodium hydroxide solution or ammonia. Dark yellow color indicated the presence of flavones.

Tests for Saponins

Frothing Test: The samples were shaken well with water and formation of copious lather indicated the presence of saponins.

Test for Alkaloids

Mayer's reagent: To the sample few drops of acetic acid and Mayer's reagent was added and shaken well. A creamy white colored precipitation indicated the presence of alkaloids.

Wagner's reagent: To the sample, few drops of acetic acid and Wagner's reagent was added and shaken well. A reddish brown precipitation indicated the presence of alkaloid.

Test for Quinones

To the sample, sodium hydroxide was added. Blue and green or red color indicated the presence of quinones.

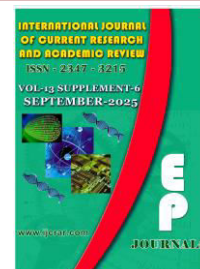


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Test for Proteins

Biuret Test: To the sample few drops of Biuret reagent was added and formation of blue colour indicated the presence of protein.

Test for Tannins

Lead Acetate Test: The samples were mixed with basic lead acetate solution. Formation of orange red precipitate indicated the presence of tannins.

Anti-Oxidant Assay

In-vitro DPPH Radical scavenging activity

This method is a simple, rapid and sensitive method to measure the antioxidant activity of any compound (Koleva *et al.*, 2002). DPPH is a stable free radical with purple in colour, readily accepts the hydrogen from the antioxidants and the colour change from purple to yellow. 2,2-Diphenyl-1-picrylhydrazyl will get converted to 2,2-Diphenyl-1-picrylhydrazine when combined with the antioxidant.

$$\% \text{ of inhibition} = (\text{Abs of control} - \text{Abs of test}) / \text{Abs of control} \times 100.$$

Results and Discussion

Phytochemical Analysis

The phytochemicals analysis in Table. *Acalypha indica* in Hexane and Ethyl acetate.

S.no	Phytochemical Parameters	Hexane	Ethyl acetate
1.	Test for Phenolic Compounds	-	-
2.	Test for Reducing Sugar	-	-
3.	Test for Flavones	+++	+++



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4.	Test for Saponins	-	-
5.	Test for Alkaloids (Wagner's Test)	+++	+++
6.	Test for Alkaloids (Mayer's Test)	-	+++
7.	Test for Quinones	-	-
8.	Test for Proteins	-	-
9.	Test for Tannins	-	-

Phytochemical constituents of *Acalypha indica* in Hexane. Presence of Flavones and Alkaloids.

Phytochemical constituents of *Acalypha indica* in Ethyl Acetate. Presence of Flavones and Alkaloids

DPPH ASSAY

DPPH assay activity of Hexane extract of *Acalypha indica*

% of inhibition = (Abs of control - Abs of test) / Abs of control x100

Control - 0.6255

Concentration µg/ml	% inhibition AS	% inhibition AI
50	79.53	20.75
100	78.73	27.52
150	80.17	38.21
200	82.57	51.35
250	88.80	61.44



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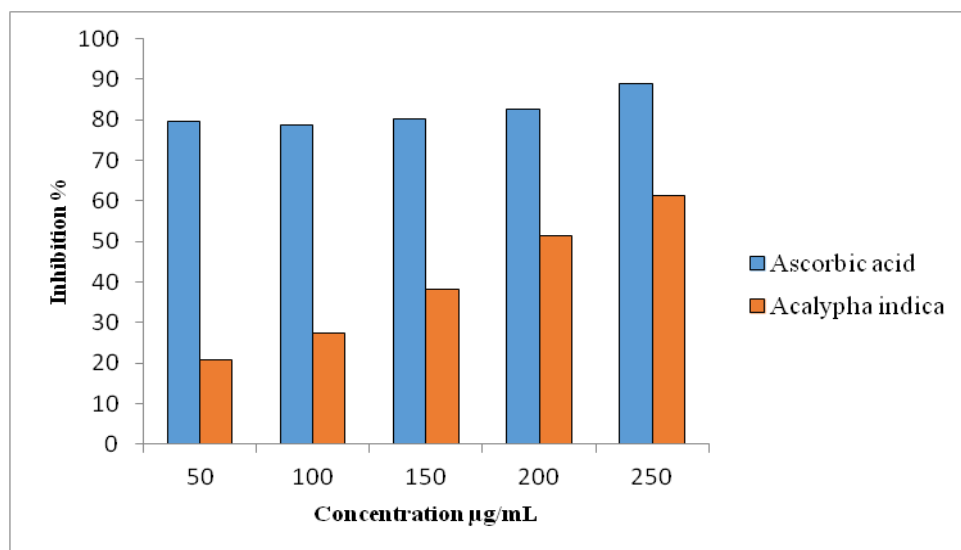


Fig 105.5 Phytochemical constituents of *Acalypha indica* in Hexane

DPPH radical scavenging assay of Ascorbic acid (standard) and Hexane extract of *Acalypha indica*

DPPH assay activity of Ethyl acetate extract of *Acalypha indica*

$$\% \text{ of inhibition} = (\text{Abs of control} - \text{Abs of test}) / \text{Abs of control} \times 100$$

Control - 0.6255

Concentration µg/ml	% inhibition AS	% inhibition AI
50	79.53	17.25
100	78.73	32.91
150	80.17	50.91
200	82.57	71.22
250	88.80	81.48



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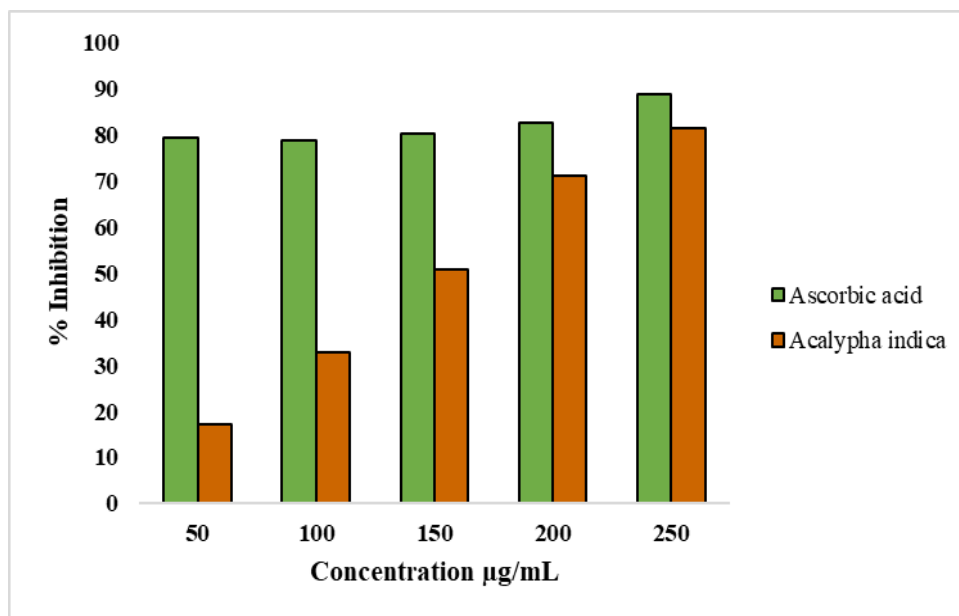


Fig 105.6 Phytochemical constituents of *Acalypha indica* in Ethyl acetat

DPPH radical scavenging assay of Ascorbic acid (standard) and Hexane extract of *Acalypha indica*

Discussion

Acalypha indica, commonly known as Indian nettle or Indian copperleaf, holds significant promise as a medicinal plant due to its rich ethnobotanical heritage and diverse pharmacological properties. The extensive literature on *Acalypha indica* highlights its traditional uses in treating various ailments and its potential therapeutic benefits supported by scientific studies.

The plant's phytochemical composition, in hexane and ethylacetate extract of *Acalypha indica* shows the presence of flavones & alkaloids, which contributes to its wide range of biological activities, such as antioxidant properties. The DPPH assay of *Acalypha indica* in hexane extract has lowest inhibition than ethyl acetate extract. The DPPH Assay of *Acalypha indica* in



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Ethyl acetate extract has increasing rate of inhibition as the concentration increases. This shows the maximum inhibition of 81.48 % at 250µg/ml Concentration. *Acalypha indica* known for its medicinal properties in traditional medicine systems, particularly in Ayurveda and traditional Chinese medicine. *Acalypha indica* is known for its medicinal properties in traditional medicine systems, particularly in Ayurveda and Traditional Chinese Medicine. From scientific research, it is said to be used to treat various ailments such as skin diseases, wounds, respiratory issues, and gastrointestinal problems.

Conclusion

The present study focused on Phytochemical analysis and Anti oxidant activity of *Acalypha indica*, a traditionally used medicinal plant. The results of this study demonstrate that *Acalypha indica* possesses significant antioxidant activity, which can be attributed due to the presence of various phytochemical constituents, including flavones, Alkaloids.

The antioxidant activity of *Acalypha indica* was evaluated using in vitro DPPH assays which revealed that the plant extract exhibits potent antioxidant activity. The phytochemical analysis of the plant revealed the presence of various bioactive compounds, which are known for their antioxidant and pharmacological properties.

The findings of this study suggest that *Acalypha indica* can be a potential source of natural antioxidants, which can be used in the prevention and treatment of various oxidative stress-related diseases.

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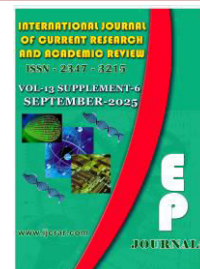


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Full Length Article

IJCRAR/FL/115

Phytochemical Screening of Aqueous Seed Extract of *Trachyspermum ammi* and its Relevance to Traditional Medicine

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Abstract

Trachyspermum ammi (Ajwain) is a medicinally important spice widely used in traditional systems of medicine across Asia and the Middle East. The present study investigates the phytochemical constituents of aqueous seed extract of *T. ammi* using qualitative screening methods. The extract revealed the presence of alkaloids, flavonoids, tannins, glycosides, steroids, phenols, carbohydrates, and proteins, while saponins and terpenoids were absent. These bioactive metabolites are known to confer antimicrobial, antioxidant, and anti-inflammatory activities, thereby validating its ethnopharmacological applications. This study highlights the potential of *T. ammi* as a source of therapeutic compounds and emphasizes the need for advanced chromatographic and spectroscopic characterization in future work.

Keywords: *Trachyspermum ammi*, Ajwain, phytochemical analysis, aqueous extract, medicinal plants

Introduction

Medicinal plants remain an essential resource for drug discovery, with approximately 80% of the world's population depending on traditional medicine for primary healthcare [1]. Among them, *Trachyspermum ammi* (L.), commonly called ajwain, bishop's weeds or carom seeds, is a spice belonging to the family Apiaceae. Traditionally, it has been employed in



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Ayurveda, Unani, and folk practices for treating gastrointestinal disorders, respiratory ailments, microbial infections, and inflammatory conditions [2].

Phytochemical investigations have shown that ajwain is rich in secondary metabolites such as thymol, alkaloids, flavonoids, and phenolics, which contribute to its pharmacological properties including antioxidant, antimicrobial, antispasmodic, and hepatoprotective activities [3]. However, despite its wide use, systematic qualitative analysis of aqueous extracts is limited.

This study aims to evaluate the phytochemical constituents of aqueous seed extracts of *T. ammi* and correlate the results with its traditional uses.

Fig 106.1 *Trachyspermum ammi* (L.) Sprague fruits



Materials and Methods

Plant Material Preparation

Dried seeds of *Trachyspermum ammi* were procured from a certified herbal medicine store. The seeds were cleaned, shade-dried, and powdered using a mechanical grinder. The powdered sample was stored in airtight containers until further use.

Extraction Procedure

Five grams of powdered seeds were mixed with 25 mL of sterile distilled water and heated at 50–60°C for 30 minutes. The mixture was filtered using Whatman No.1 filter paper and



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centrifuged at 2500 rpm for 15 minutes. The supernatant was collected and refrigerated at 5°C for subsequent analysis.



Fig 106.2 Aqueous extracts of *T. ammi* seeds

Phytochemical Screening

Standard qualitative tests were performed for different classes of phytoconstituents [4] with minor modifications:

- i. **Test For Alkaloids (Wagner's test):**
5ml of 1% 2N HCl was mixed with the crude extract and heated gently. After heating, Wagner's reagent was added to the mixture. The appearance of turbidity or precipitate indicates the presence of alkaloids.
- ii. **Test For Flavonoids:**
5 ml of extract was mixed with 1 mL of 10% sodium hydroxide solution, which produces yellow coloration. On addition of 1 mL of dilute hydrochloric acid, the solution changes from yellow to colorless, indicating the presence of flavonoids.
- iii. **Test For Glycoside (Salkowski's test):**
2 ml of chloroform was mixed with the crude extract, followed by the addition of 2 mL of concentrated sulfuric acid. The mixture was shaken gently, and the appearance of a reddish-brown color indicates the presence of glycosides.
- iv. **Test For Tannin**

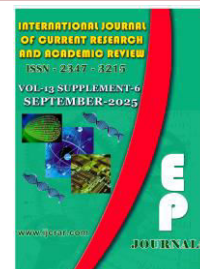


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1 ml of distilled water and 2-3 drops of ferric chloride solution were added to 0.5 ml of crude extract. The development of coloration confirms the presence of tannins.

v. Test For Saponins:

1 ml of crude extract was mixed with 5 ml of distilled water in a test tube and shaken vigorously. The formation of a stable foam indicates the presence of saponins.

vi. Test For Steroids:

2 ml of chloroform was added to the crude extract, followed by 2 ml each of concentrated H_2SO_4 and acetic acid. The appearance of a greenish color indicates the presence of steroids.

vii. Test For Terpenoids:

The crude extract was mixed with 2 ml of chloroform and evaporated to dryness. To this residue, 2 ml of concentrated H_2SO_4 was added and heated for about 2 minutes. A greenish coloration at the interface indicates the presence of terpenoids.

viii. Test For Carbohydrates (Iodine test):

2 ml of iodine solution was mixed with 0.5-1 ml of crude extract. The development of a dark blue or purple coloration indicates the presence of carbohydrates.

ix. Test For Phenol:

2 ml of alcohol and 2-3 drops of ferric chloride solution were added to 1 ml of crude extract. The appearance of blue-green or black coloration confirms the presence of phenols.

x. Test For Protein (Biuret test):

2 ml of Biuret reagent was added to 2 ml of extract. The mixture was shaken well and warmed for 5 minutes. The appearance of a red or violet color indicates the presence of proteins.

Results

Test	Observation	Inference
Alkaloids	Precipitate observed	Positive
Flavonoids	Yellow color turning colorless with HCl	Positive
Glycosides	Reddish-brown interface	Positive
Tannins	Development of coloration	Positive
Saponins	No stable foam	Negative

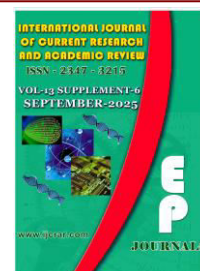


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Steroids	Greenish coloration	Positive
Terpenoids	No green interface	Negative
Carbohydrates	Blue coloration with iodine	Positive
Phenols	Blue-green coloration	Positive
Proteins	Violet coloration	Positive



Figure 3: Test for Alkaloids & Flavonoids

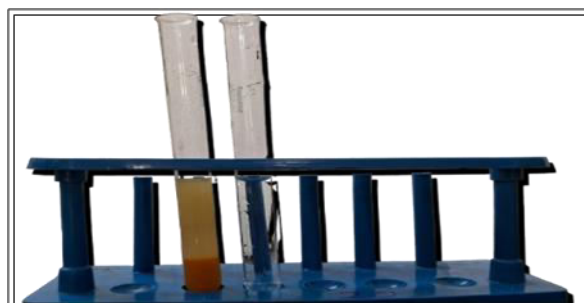


Figure 4: Test for Tannins

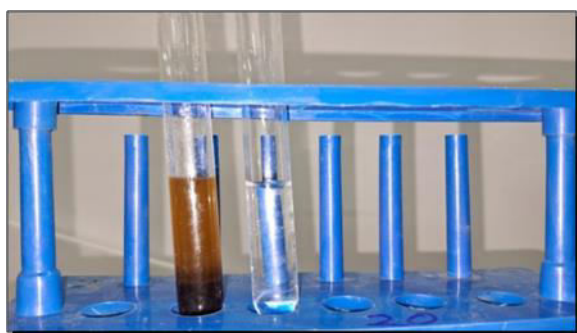


Figure 5: Test For Glycosides

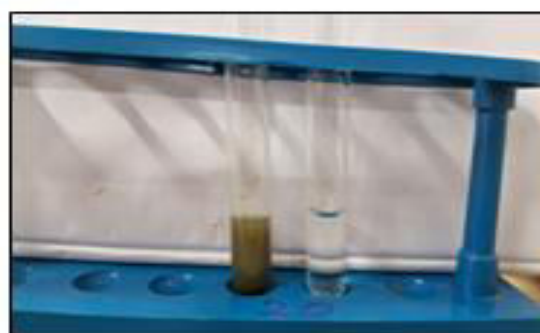


Figure 6: Test For Steroids

The extract contained a broad range of phytochemicals including alkaloids, flavonoids, tannins, steroids, phenols, carbohydrates, and proteins, while saponins and terpenoids were absent.

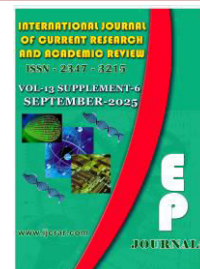


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Discussion

The phytochemical profile obtained in this study supports the ethnopharmacological use of *T. ammi*. Alkaloids and flavonoids are well-documented for their antimicrobial and antioxidant properties, which may explain the plant's traditional use in treating infections and inflammation [2]. Presence of tannins and phenols further suggests potential for wound healing and free radical scavenging activities [3]. Steroids contribute to anti-inflammatory properties, while carbohydrates and proteins reflect nutritional aspects of the seeds.

The absence of saponins and terpenoids in the aqueous extract indicates solvent selectivity, as these compounds are more soluble in organic solvents. Previous studies have confirmed the abundance of thymol, a monoterpene phenol, in essential oil fractions [4], which may not be efficiently extracted in aqueous medium.

Overall, the findings validate the medicinal relevance of *T. ammi* and provide a baseline for further advanced studies employing chromatographic separation (HPLC, GC-MS) and bioactivity assays to isolate specific compounds responsible for therapeutic effects.

Conclusion

The aqueous extract of *Trachyspermum ammi* seeds contains diverse phytochemicals including alkaloids, flavonoids, tannins, steroids, phenols, carbohydrates, and proteins, while lacking saponins and terpenoids. These metabolites substantiate its traditional medicinal applications against gastrointestinal disorders, infections, and inflammatory diseases. Further in-depth research involving compound isolation and pharmacological testing is warranted to develop novel therapeutic agents from *T. ammi*.

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Full Length Article

IJCRAR/FL/116

Phytochemical Screening of Aqueous Extract of *Plectranthus amboinicus* (Karpooravalli)

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Abstract

Plectranthus amboinicus is one of the medicinal plants commonly available in different parts of the world and this plant is used in Indian system of medicine to cure various diseases in human and animals. The phytochemical analysis of *Plectranthus amboinicus* revealed a rich presence of bioactive secondary metabolites such as alkaloids, flavonoids, terpenoids, tannins, and phenolics, which are known to possess various pharmacological properties including antioxidant, antimicrobial, anti-inflammatory, and antidiabetic effects. The presence of flavonoids and phenolics supports the plant's antioxidant potential, helping to neutralize free radicals and reduce oxidative stress. Saponins and tannins contribute to the plant's antimicrobial and astringent properties, aligning with its traditional use in treating respiratory and digestive disorders. The absence or trace levels of sterols suggest limited hormonal activity. The present study intends further research on selected bioactive compounds and phytochemicals from treating respiratory tract and digestive ailments.

Keywords: *Plectranthus amboinicus*, Karpooravalli, phytochemical analysis, aqueous extract

Introduction

Plectranthus amboinicus, a member of the Lamiaceae family, is a fragrant herb widely used in traditional medicine for treating respiratory ailments, skin diseases, and other conditions. The plant's leaves are known for their aromatic and medicinal properties, making them a valuable resource for various remedies.

Plectranthus amboinicus is the scientific name for the Karpooravalli plant. Traditionally, Karpooravalli has been used to cure colds and coughs in adults and newborns. It helps weight



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reduction, promotes hair development, treats fever and asthma, and treats hair issues including dandruff and grey hair. The plant contains a variety of phytochemicals, which are biologically active compounds found in plants.

Previous studies have shown that *Plectranthus amboinicus* contains various bioactive compounds, including alkaloids, glycosides, tannins, saponins, terpenoids, and flavonoids, which are responsible for its medicinal properties.

Traditional uses of the plant include treating respiratory issues like asthma, bronchitis, malaria, renal/ vesical calculi, convulsions and epilepsy as well as skin conditions. The Tamil names are Karpoor Valli, Omavalli, and Karpuravalli. In English, it is frequently referred to as Spanish thyme, Mexican mint, Indian mint, Mexican oregano, and Indian boreage. Extracting bioactive compounds from the leaves using aqueous extracts, identifying the presence of various phytochemicals through qualitative and quantitative analysis and evaluating the antimicrobial activity of the extracts against selected bacterial and fungal strains are the need of the hour.

Materials and Methods

1. Plant material collection and preparation

Generally fresh leaves were collected from the garden and washed 2-3 times with running tap Water in order to remove the impurities from the leave materials. The leave materials was dried in air under Shade after it dried the plant materials was grind with the help of mixer, The powder was kept in small plastic Containers or zip lock cover with proper labelling.

Plant material extraction

Preparation of aqueous extracts in the first grind leaf materials, take 5gm of leaf powder and weighed by using an electronic balance then 5gm of plant material were crushed in 25ml of sterile water then heated at 50-60°C Then it was filtered by using whattman. filter paper. The filtrate was centrifuged at 2500 rpm for 15min and Filtrate was collected in sterile bottle and stored in the refrigerator at 5°C now the filtrate was ready for test Analysis.

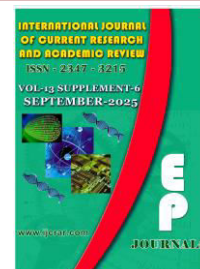


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Phytochemical Analysis of Aqueous Extracts of *Plecranthus amboinicus*

Test for alkaloids

5ml of 1% of 2N Hydrochloric acid was mixed with crude extract and heated gently. After heating, Wagner's Reagent was added to the mixture, and turbidity indicates the presence of alkaloids.

Test for Flavanoids

5ml of extract was taken in 1 ml of 10% solution of sodium hydroxide, its appears in yellow colors and add 1ml of dilute hydrochloric acid its change into yellow to colourless due to the presence of alkaloids and add 2ml of dilute hydrochloric acid.

Test for Glycoside

2ml of chloroform was mixed with crude extract. Then add 2ml of concentrated sulphuric acid was added carefully and shaken gentle. A reddish brown color indicates the presence of glycosides.



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Test for Tannin

1ml of distilled water and 2-3 drops of ferric chloride solution was added to 0.5 ml crude extract. A coloration indicates the presence of tannin.

Test for Saponins

1ml of crude extract was mixed with 5 ml of distilled water in test tube and its shaken vigorously. the formation of stable foam was taken as an indication for the presence of Saponins.

Test for Steroids

2ml of chloroform was added to the crude extract. Then 2ml of concentrated sulphuric acid and acetic acid were added to the mixture. The appearance of greenish coloration in the reaction mixture was indicating the presence of steroids.

Test for Terpenoids

The crude extract was mixed with 2ml of chloroform and evaporated the dryness. To this, 2ml of concentrated sulphuric acid was added and heated for about 2mts. Presence of terpenoids was indicate the greenish color at the interface.

Test for Carbohydrates

2ml of iodine solution was mixed with 0.5 to 1 ml of crude extract. A dark blue or purple coloration indicates the presence of carbohydrates.

Test for Phenol

2ml of alcohol and 2-3 drops of ferric chloride solution was added to 1ml of crude extract, blue green or black coloration indicates the presence of phenol.



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Test for protein

Biuret test- 2ml of biuret reaction was added to 2ml of extract. The mixture was shaken well and warm for 5mins. Appearance of red or violet color indicates the presence of proteins.

Result and Discussion

The phytochemical analysis of *Plectranthus amboinicus* revealed a rich presence of bioactive secondary metabolites such as alkaloids, flavonoids, terpenoids, tannins, saponins and phenolics, which are known to possess various pharmacological properties including antioxidant, antimicrobial, anti-inflammatory, and antidiabetic effects. The presence of flavonoids and phenolics supports the plant's antioxidant potential, helping to neutralize free radicals and reduce oxidative stress. Saponins and tannins contribute to the plant's antimicrobial and astringent properties, aligning with its traditional use in treating respiratory and digestive disorders. The absence or trace levels of sterols suggest limited hormonal activity.

These findings are consistent with previous studies on *P. amboinicus* and validate its use in folk medicine. The identified compounds may serve as a basis for the development of plant-based therapeutic agents.

SNO	TEST	OBSERVATION
1	Alkaloids	Positive
2	Flavaniods	Positive
3	Tannin	Positive
4	Saponin	Positive
5	Steroids	Negative
6	Terpenoids	Positive
7	Carbohydrates	Positive
8	Phenol	Positive
9	Protein	Negative
10	Glycosides	Negative

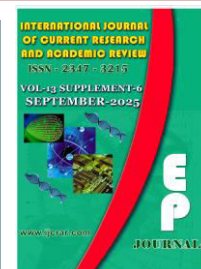


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Conclusion

The study will be concluded by summarizing the key findings regarding the phytochemical composition and antimicrobial activity of *Plectranthus amboinicus*. The results will highlight the potential of this plant as a source of natural remedies and support its traditional uses. Further research may be recommended to explore the specific mechanisms of action of the identified compounds and to investigate their potential in treating various diseases.

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Full Length Article

IJCRAR/FL/117

Phytochemical Analysis of Aqueous Extract of *Solanum trilobatum*

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Abstract

Solanum trilobatum is one of the medicinal plants commonly available in different parts of the world and this plant is used in Indian system of medicine to cure various diseases in human and animals. Phytochemical screening of this aqueous extract proved the presence of major bioactive ingredients such as alkaloids, flavonoids, saponins, sterols, glycosides, protein, amino acid, terpenoids, quinones and absence of tannins, anthraquinone, fixed oils, carotenoid, phenols and carbohydrates in various parts of the plant including leaf, stem, root, flowers and berries to treat various diseases like tuberculosis, respiratory problems and bronchial asthma. The present study intends further research on selected bioactive compounds and phytochemicals from *Solanum trilobatum* in treating a tumor, cancer cells, and other diseases also involve in upsurge the immunity.

Keywords: *Solanum trilobatum*, phytochemical activity, aqueous extract

Introduction

The *Solanum trilobatum* L. thuthuvalai is a well-known medicinal plant in India. The leaves are used for respiratory, liver and digestive problems, among others, but they are also eaten as a vegetable in India and Sri Lanka. It is a climbing shrub that can eventually grow to 2-3 metres tall. The flowers are purple and have yellow pistils and stamens. After pollination, red to dark purple berries develop that are edible after ripening. Give the plant a sunny spot and well-drained soil. The species can withstand drought well and is best kept as a houseplant or in a

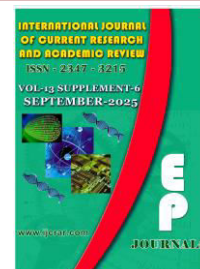


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greenhouse. The extracts from the leaves are used to boost male fertility and treat snake poisoning. Solanum is the chemical in this plant that suppresses tumour growth. Therapeutic plants are a local heritage with worldwide significance, and the globe is endowed with a vast array of medicinal plants.

Materials and Methods

Generally fresh leaves were collected from the garden and washed 2-3 times with running tap Water in order to remove the impurities from the leave materials. The leave materials was dried in air under Shade after it dried the plant materials was grind with the help of mixer, The powder was kept in small plastic Containers or zip lock cover with proper labelling.

Plant Material Collection and Extraction

Preparation of aqueous extracts in the first grind leaf materials, take 5gm of leaf powder and weighed by using an electronic balance then 5gm of plant material were crushed in 25ml of sterile water then heated at 50-60°C. Then it was filtered by using whattman filter paper, the filtrate was centrifuged at 2500 rpm for 15min and Filtrate was collected in sterile bottle and stored in the refrigerator at 5°C now the filtrate was ready for test Analysis.

Phytochemical Analysis of Aqueous Extracts of *Plecranthus amboinicus*

Test for alkaloids

5ml of 1% of 2N Hydrochloric acid was mixed with crude extract and heated gently. After heating, Wagner's Reagent was added to the mixture, and turbidity indicates the presence of alkaloids.

Test for Flavanoids

5ml of extract was taken in 1 ml of 10% solution of sodium hydroxide, its appears in yellow colors and add 1ml of dilute hydrochloric acid its change into yellow to colourless due to the presence of alkaloids and add 2ml of dilute hydrochloric acid.



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Test for Glycoside

2ml of chloroform was mixed with crude extract. Then add 2ml of concentrated sulphuric acid was added carefully and shaken gentle. A reddish brown color indicates the presence of glycosides.

Test for Tannin

1ml of distilled water and 2-3 drops of ferric chloride solution was added to 0.5 ml crude extract. A coloration indicates the presence of tannin.

Test for Saponins

1ml of crude extract was mixed with 5 ml of distilled water in test tube and its shaken vigorously. The formation of stable foam was taken as an indication for the presence of Saponins.

Test for Steroids

2ml of chloroform was added to the crude extract. Then 2ml of concentrated sulphuric acid and acetic acid were added to the mixture. The appearance of greenish coloration in the reaction mixture was indicating the presence of steroids.

Test for Terpenoids

The crude extract was mixed with 2ml of chloroform and evaporated the dryness. To this, 2ml of concentrated sulphuric acid was added and heated for about 2mts. Presence of terpenoids was indicate the greenish color at the interface.

Test for Carbohydrates

2ml of iodine solution was mixed with 0.5 to 1 ml of crude extract. A dark blue or purple coloration indicates the presence of carbohydrates.



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Test for Phenol

2ml of alcohol and 2-3 drops of ferric chloride solution was added to 1ml of crude extract, blue green or black coloration indicates the presence of phenol.

Test for protein

Biuret test- 2ml of biuret reaction was added to 2ml of extract. The mixture was shaken well and warm for 5mins. Appearance of red or violet color indicates the presence of proteins.

Results and Discussion



Qualitative Phytochemical Screening

In aqueous extract of *S. trilobatum*, presence of alkaloids, flavonoids, saponins, sterols, glycosides, protein, amino acid, terpenoids, quinones and absence of tannins, anthraquinone, fixed oils, carotenoid, phenols and carbohydrates were observed (Table 1). The presence and absence of the phytoconstituents depends on the solvent medium used for extraction and the physiological property of individual taxa.

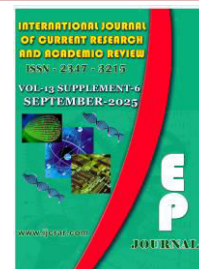


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SNO	TEST	OBSERVATION
1.	Alkaloids	Positive
2.	Flavanoids	Positive
3.	Tannin	Negative
4.	Saponin	Positive
5.	Sterols	Positive
6.	Terpenoids	Positive
7.	Carbohydrates	Negative
8.	Phenol	Negative
9.	Protein	Positive
10.	Glycosides	Positive

Conclusion

The current study highlights the physio-chemical evaluation of drugs as important parameters in detecting the components as drug for application. So, plant extracts containing alkaloids, flavanoids, phenolic, proteins, amino acid, sterols, fixed oil, carotenoid, carbohydrate, terpenoids, tannin, cardiac glycosides, saponin, quinones and anthroquinones were all analysed qualitatively tests also includes alkaloids, flavanoids, tannins, Terpenoids, saponins, proteins, cardiac glycosides and amino acid. More studies on Identification of bioactive compounds and isolation of active principles could be further studied for their potential medicinal properties.

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Full Length Article

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Machine Learning Methodology and Applications

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Abstract

Machine Learning (ML), a subset of Artificial Intelligence (AI), has rapidly emerged as one of the most powerful technologies of the 21st century. By enabling systems to learn from data and improve performance without explicit programming, ML has found applications across various domains, including healthcare, business, and education. In the context of higher education, ML offers significant opportunities to enhance teaching, learning, and administrative processes. This paper explores the potential applications of machine learning in higher education, focusing on student performance prediction, personalized learning, and academic decision-making. ML algorithms such as supervised, unsupervised, and reinforcement learning are utilized to analyze large volumes of student data, including academic records, attendance, and feedback. Predictive models can identify students at risk of dropout, enabling timely intervention by faculty. Recommendation systems, similar to those used by platforms like Netflix and Amazon, can provide personalized course and resource suggestions, thereby improving student engagement. Furthermore, ML can automate grading systems, detect plagiarism in assignments, and support the development of intelligent tutoring systems. Despite these advantages, the adoption of ML in higher education faces challenges such as data privacy concerns, algorithmic bias, and the requirement for large, high-quality datasets. However, with proper data governance and continuous model improvement, ML can become a vital tool in creating smarter, data-driven educational environments. The findings of this study suggest that machine learning can significantly transform the future of higher education by making it more efficient, personalized, and student-centered. Institutions that integrate ML technologies will be better equipped to address the challenges of modern education and prepare learners for a rapidly evolving digital world.

Keywords: Machine Learning, Higher Education, Predictive Analytics, Personalized Learning, Artificial Intelligence



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Introduction

The 21st century is witnessing an unprecedented growth of digital technologies that are reshaping every aspect of human life. Among these technologies, Artificial Intelligence (AI) and its subfield, Machine Learning (ML), stand out as game changers. Machine Learning refers to the ability of computer systems to learn patterns from data, adapt to changes, and make predictions or decisions with minimal human intervention. Unlike traditional programming, where every rule must be explicitly defined, ML algorithms improve their performance through experience, much like humans.

In recent years, ML has become a powerful tool in sectors such as healthcare, finance, transportation, and e-commerce. From detecting fraudulent transactions to recommending movies on Netflix, ML has seamlessly integrated into daily life. The education sector, however, has been relatively slower in adopting ML compared to other industries. Yet, the challenges faced by higher education institutions—such as increasing student enrollment, diverse learning needs, and administrative complexity—make ML a promising solution for transforming the academic environment.

Traditional methods of education and administration often fall short in addressing the individual needs of students. Teachers struggle with large classes, limited time, and diverse learning abilities. Similarly, administrators must manage vast amounts of data related to student performance, attendance, examinations, and resource allocation. Machine Learning offers a way to analyze this data effectively and provide actionable insights.

The objective of this paper is to explore the role of ML in higher education, focusing on its applications in student performance prediction, personalized learning, academic decision-making, and administrative efficiency. It also highlights the challenges and ethical concerns associated with ML adoption. By studying these aspects, the paper emphasizes that Machine Learning has the potential to revolutionize higher education by making it more efficient, data-driven, and student-centered.

Literature Review

Machine Learning has been the subject of increasing research in the field of education. Early studies focused on applying basic algorithms to predict student success based on exam



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results and attendance records. More recent research has expanded into areas such as adaptive learning systems, intelligent tutoring, and large-scale educational analytics.

Jordan and Mitchell (2015) defined ML as a scientific discipline that enables systems to improve automatically through experience. Their work emphasized its broad applicability in domains including education. Kumar and Sharma (2021) highlighted how ML-based predictive models could identify students at risk of dropping out, enabling teachers and administrators to intervene early. Similarly, Chen et al. (2018) examined the role of ML in creating recommendation systems for online learning platforms, which suggest personalized resources to students.

Research has also investigated the use of ML in detecting plagiarism. Algorithms that compare student assignments against vast online databases can identify similarities and ensure academic integrity. Another significant area is automated grading, where supervised learning models are trained to evaluate essays and answer scripts, reducing faculty workload.

Despite these advancements, gaps remain in the research. Many ML applications in education are still experimental and have not been adopted at scale. Data privacy is another concern, as educational institutions handle sensitive information about students. Moreover, algorithmic bias can create unfair outcomes if training data is not diverse. These gaps highlight the need for more robust, ethical, and large-scale applications of ML in higher education.

Methodology

This paper uses a conceptual and analytical approach, reviewing existing research and identifying practical applications of ML in higher education. It does not involve primary experimentation but focuses on synthesizing current knowledge and proposing a model for implementation.

The methodology involves:

1. Algorithms:

Supervised Learning → Used for predicting student performance based on labeled data (attendance, grades).

Unsupervised Learning → Used for clustering students into groups based on learning styles.



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Reinforcement Learning → Used for adaptive learning platforms that reward students for correct answers and adjust content dynamically.

Tools and Platforms:

Widely used platforms such as TensorFlow, Scikit-learn, Weka, and Google Cloud ML can support the development of ML applications for education.

Data Sources:

Data typically comes from institutional databases, online learning platforms, learning management systems (LMS), and student feedback surveys. The data is pre-processed, analyzed, and used to train ML models.

This methodology allows us to examine how ML can be practically applied in student learning, academic evaluation, and administrative decision-making.

Applications / Case Study

Student Performance Prediction

ML algorithms can analyze past exam scores, attendance records, and participation in classroom activities to predict future performance. Teachers can use these predictions to identify at-risk students and provide remedial support before it is too late.

Personalized Learning

Recommendation systems, similar to those used by Netflix and Amazon, can be adapted for education. Based on a student's past learning behavior, ML can suggest courses, reading materials, and practice exercises. This ensures that each student receives a learning path tailored to their needs.

Automated Grading

Supervised ML models trained on previous grading patterns can automatically evaluate objective-type and even descriptive answers. This reduces the burden on teachers and ensures faster feedback to students.



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Plagiarism Detection

ML algorithms compare student submissions with online sources and institutional databases to detect copied content. This not only upholds academic integrity but also teaches students the value of originality.

Intelligent Chatbots

ML-powered chatbots can provide 24/7 academic support, answering queries about admission, timetables, exams, and general academic information. Unlike rule-based systems, ML-enabled chatbots learn from interactions and improve over time.

Case Example: A model implemented in a university in the United States used ML to analyze online course activity and predict student dropout rates. The system achieved an accuracy of 85% in identifying at-risk students, allowing the institution to provide timely counseling and reduce dropout rates.

Results & Discussion

The applications of ML in higher education bring numerous benefits. Predictive models help in timely intervention for struggling students, recommendation systems increase student engagement, and automated grading saves time for faculty. Additionally, plagiarism detection ensures academic honesty, and chatbots improve student access to information.

However, several challenges persist. Data privacy is a major concern, as student information is sensitive and requires strict protection. Algorithm bias can also result in unfair outcomes if the training data is not diverse. For example, if a model is trained only on data from high-performing students, it may unfairly predict poor performance for average learners. Another challenge is the requirement of high-quality datasets, which many institutions lack. Implementation costs are also high, particularly for smaller colleges with limited resources.

Despite these limitations, the overall impact of ML on higher education is positive. By adopting proper data governance policies, ensuring algorithm transparency, and using diverse datasets, institutions can maximize the benefits while minimizing risks.



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Future Scope

The future of ML in higher education is promising. Virtual tutors powered by ML can provide personalized guidance to students, acting as academic mentors. Emotion recognition systems may help identify students who are stressed or disengaged, enabling timely psychological support.

Integration of ML with Virtual Reality (VR) and Augmented Reality (AR) can create immersive learning experiences. Imagine a history student virtually walking through ancient civilizations or a biology student exploring a 3D model of the human body, all guided by ML algorithms that adapt the experience to the learner's pace.

Moreover, voice-enabled assistants like Alexa and Siri can be adapted for academic use, helping students with scheduling, study reminders, and answering subject-related questions. Multilingual support in ML systems will also make education more inclusive by addressing the needs of students from different linguistic backgrounds.

Conclusion

Machine Learning has immense potential to transform higher education. From predicting student performance to creating personalized learning paths, from automating grading to ensuring academic integrity, ML applications make education more efficient and student-centered. While challenges such as privacy concerns and algorithmic bias remain, they can be addressed with ethical practices and robust data management policies. The integration of ML into higher education is not just a technological advancement; it represents a shift toward data-driven, personalized, and inclusive learning environments. Institutions that embrace ML will be better prepared to meet the challenges of the digital age and equip students with the skills needed for the future.

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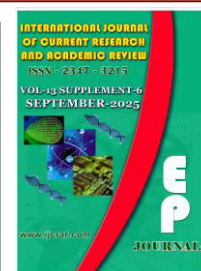


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Full Length Article

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Solar Power Prediction Using Machine Learning

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Abstract

The transition from fossil fuels to renewable energy is one of the most important challenges of the 21st century. Among renewables, solar photovoltaic (PV) power is projected to dominate the global energy landscape due to its abundance, scalability, and declining installation costs. However, the major drawback of solar power lies in its intermittent and variable nature. Environmental conditions such as cloud cover, atmospheric humidity, wind speed, and irradiance directly influence PV system performance, making accurate forecasting extremely difficult. Accurate solar forecasting is vital for grid operators, energy storage providers, and smart city planners. Without reliable forecasts, electricity grids face imbalances, energy storage systems are mismanaged, and large-scale integration of renewables becomes unreliable. While traditional forecasting techniques such as ARIMA and persistence-based models provide simple baselines, they often fail to capture the nonlinear and highly dynamic patterns of solar energy generation. In this research project, we developed a machine learning framework for short-term solar power prediction using a synthetic dataset that includes weather, irradiance, and PV system parameters. Experimental results demonstrated that while Linear Regression provided a baseline, Random Forest attempted to capture nonlinear dependencies. However, both models showed limited predictive accuracy due to the synthetic nature of the dataset. Despite this, the framework highlights the strength of ML-based forecasting systems and sets the stage for future extensions using real-world datasets and deep learning methods such as LSTM and GRU networks. This project contributes to the broader field of renewable energy forecasting by providing insights into machine learning applications for solar forecasting. The framework can be integrated with IoT-enabled sensors, weather APIs, and real-time monitoring systems, ultimately supporting smart grid optimization, predictive maintenance, and sustainable energy development.

Keywords: Solar Power, solar photovoltaic (PV)



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Introduction

The urgency of climate change mitigation and sustainable energy development has driven a global shift toward renewable sources. According to the International Energy Agency (IEA), renewable energy will account for nearly 50% of global electricity generation by 2050, with solar PV playing the most dominant role. The advantages of solar energy are undeniable: it is abundant, clean, and scalable. However, the greatest challenge of solar power lies in its intermittency. Solar generation is affected by multiple environmental and technical factors such as cloud cover, temperature, humidity, wind speed, and long-term panel degradation. For an electricity grid to remain stable, demand and supply must be balanced at all times. Fossil fuel plants can adjust their production; solar cannot. Instead, solar energy must be predicted. Traditional forecasting methods (ARIMA, persistence) assume linear or smooth patterns. However, solar generation is nonlinear, driven by chaotic weather systems. Machine Learning (ML) provides a powerful alternative. This project focuses on Linear Regression and Random Forest Regressor, comparing their effectiveness on synthetic but realistic datasets. While Linear Regression provides a benchmark, Random Forest

Problem Statement

Solar power generation is highly unpredictable due to cloud cover, irradiance variability, and other weather factors. The main problem addressed in this project is how to accurately forecast short-term solar power output using machine learning models that can handle nonlinear dependencies.

Objectives

Generate synthetic solar and weather dataset with realistic parameters. - Apply Linear Regression and Random Forest Regressor. - Compare models using MAE, RMSE, and R^2 metrics. - Visualize predictions and outputs. - Demonstrate potential applications for smart grids and energy storage.



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Literature Review

The study of solar power forecasting has evolved through multiple generations of research, starting from simple statistical methods, progressing through classical machine learning, and now incorporating deep learning and hybrid approaches. Each stage of this evolution has contributed important insights but also revealed limitations. Traditional statistical approaches such as persistence models and ARIMA provided initial benchmarks. Persistence assumes future output equals present, which fails under rapidly changing weather. ARIMA models linear dependencies well but cannot handle nonlinear chaotic weather-driven data. Exponential smoothing and regression-based methods offered slight improvements but remained inadequate for solar forecasting. Classical machine learning brought Artificial Neural Networks (ANNs), Support Vector Machines (SVMs), Decision Trees, Random Forests, and Gradient Boosting. ANNs captured nonlinearities but required large datasets. SVMs proved robust but computationally expensive. Random Forests became popular for their balance between accuracy and interpretability. Gradient Boosting (XGBoost, LightGBM) pushed accuracy further but required extensive tuning. The deep learning era introduced LSTM and GRU networks, which excel in modeling temporal dependencies in weather-driven time-series data. CNNs also contributed when combined with satellite imagery for cloud detection. Hybrid approaches combining numerical weather prediction (NWP) with ML have demonstrated state-of-the-art accuracy but rely on meteorological data access. In summary: Persistence and ARIMA are limited; ML models like RF and GBM improve performance; Deep learning offers the highest accuracy; Hybrid approaches maximize forecasting reliability. Our project focuses on Linear Regression (baseline) and Random Forest (nonlinear ensemble) as a practical demonstration of ML forecasting for solar PV.

Methodology

The dataset was generated with 8640 samples and 11 features, covering solar irradiance parameters (GHI, DNI, DHI), weather conditions (temperature, humidity, wind, cloud cover), PV system parameters (panel temperature, inverter efficiency), and lagged power outputs. Models were trained and evaluated using standard metrics: MAE, RMSE, and R^2 . Implementation was done in Python using Pandas, NumPy, Scikit-learn, and Matplotlib.



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Algorithms Used

Linear Regression

Linear Regression is a statistical method for modeling the linear relationship between dependent (solar power output) and independent variables (weather features). It assumes output is a linear combination of input features. Advantages include simplicity and interpretability, but it fails when relationships are nonlinear.

Random Forest Regression

Random Forest is an ensemble method that builds multiple decision trees and averages their predictions. It captures nonlinear dependencies and provides robustness to noise. Random Forest is effective for complex datasets, though computationally more expensive. **7. Results &**

Discussion

The models were trained and evaluated using MAE, RMSE, and R^2 metrics. Results: - Linear Regression: MAE = 15.46, RMSE = 19.70, R^2 = 0.001 - Random Forest: MAE = 15.76, RMSE = 19.99, R^2 = -0.029 Both models showed limited predictive accuracy due to synthetic dataset noise. Linear Regression provided a baseline, while Random Forest attempted to capture nonlinearities but underperformed. This underscores the need for real-world datasets or advanced time-series models (LSTM, GRU). The outputs generated during execution are shown below:

Graph of Solar Power Output:



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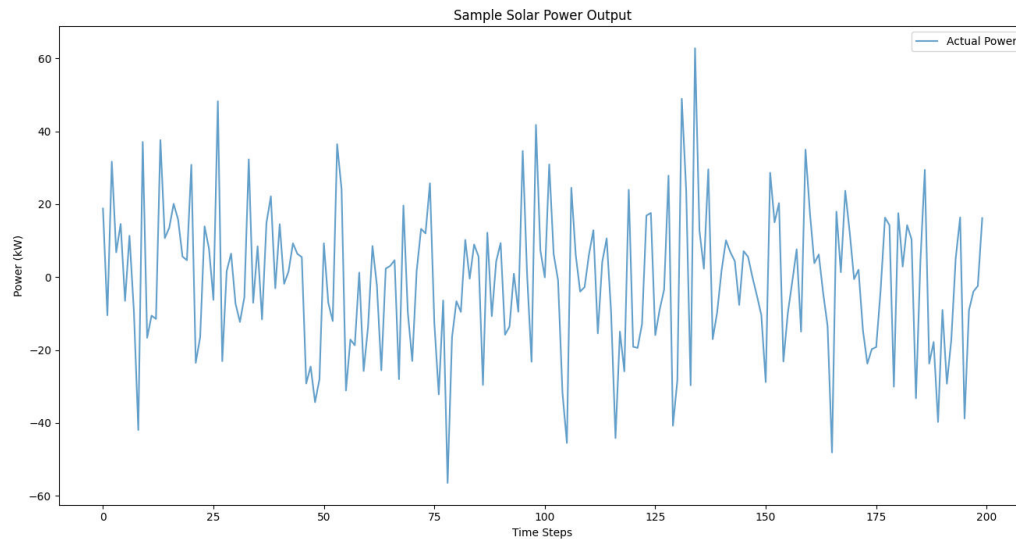
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Figure 1



Applications

Smart Grid Management: Accurate forecasting helps maintain grid stability. - Energy Storage Scheduling: Optimizes battery charging/discharging cycles. - Load Forecasting: Supports demand-response strategies. - Predictive Maintenance: Identifies inefficiencies in PV systems early.

Future Enhancements

Future improvements include: - Using real-world datasets (NREL, NASA, local weather stations). - Applying LSTM/GRU for time-series forecasting. - Building real-time dashboards for solar farm monitoring. - Integrating IoT-based weather and panel sensors with live data feeds.



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Conclusion

This project demonstrated a solar power forecasting framework using Linear Regression and Random Forest. Although results were limited by synthetic data, the framework highlights the potential of machine learning in renewable forecasting. Random Forest captured nonlinear interactions, but higher accuracy requires real-world data and advanced deep learning models. The project sets a foundation for smart grid optimization, predictive maintenance, and renewable energy integration, contributing to sustainable energy development.

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Full Length Article

IJCRAR/FL/120

Mean Edge Cordial Labeling of Wheel Structured Graphs

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Abstract

The labeling of a graph $G = (V, E)$ is defined as an injective function by labeling the vertices and edges with integers. Among the various cordial labeling of graphs that exists in the field of graph theory, the idea of mean edge cordial labeling is a new approach. For a graph G having no isolated vertex, a function $f: E(G) \rightarrow \{0, 1\}$ is called a mean edge cordial labeling of graph G , if the induced vertex labeling function is defined by the average of edges incident with each vertex be such that the number of edges with label 0 and 1 differ by at most 1, i.e., $||e||_f(0) - ||e||_f(1) \leq 1$. and the number of vertices with label 0 and 1 also differ by at most 1, i.e., $||v||_f(0) - ||v||_f(1) \leq 1$. In this paper we discuss the mean edge cordial labeling of the wheel pattern graphs such as Wheel, Helm and Gear graphs.

Keywords: Graph Labeling, Cordial Labeling, Mean Edge Labeling

Introduction

Graph labeling is an assignment of integers to vertices or edges or both vertices and edges of the graph subject to certain conditions. If the domain of the mapping is the set of vertices (or edges) then the labeling is called a vertex labeling (or an edge labeling). The origin of graph labeling can be attributed to Rosa [1] and Gallian [4]. Cordial labelling of graphs was introduced by Cahit [3] as a weakened version of graceful labeling and harmonious labeling. Graph labeling is a strong communication between number theory and structure of graphs. Mean Edge cordial

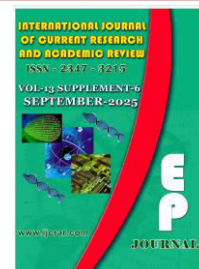


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labeling is a new concept in graph theory that involves labeling in a specific way that edges are labeled 1st and vertices are assigned labels based on the value of the labeled edges incident with that vertex. The concept of mean edge cordial labeling focuses on ensuring that the distribution of label is "cordial" or balanced in such a way that it can be applied to the both vertices and edges of the graph.

Preliminaries

This section consists of some predefined definitions that is necessary in proving the upcoming results. It is to be noted that all the graphs considered in this paper are connected and undirected.

$V(G) = \{v_i | i=1, 2, \dots, n\}$, $E(G) = \{e_j | j=1, 2, \dots, m\}$ and $f: E(G) \rightarrow \{0,1\}$ denotes the vertex set, edge set and the edge labelling function of the graph G respectively. A **Cycle** [10] is a sequence of distinct vertices $(v_0, v_1, v_2, \dots, v_{(n-1)}, v_0)$ where v_i and $v_{(i+1)}$ are adjacent and is denoted by C_n . A wheel graph is a graph formed by connecting a single vertex to all vertices of a cycle. The helm graph is obtained by adjoining a pendant edge at each node of the outer cycle for a n -wheel graph where n denotes the number of vertices. The gear graph is obtained from the wheel graph by subdividing each of its rim edge.

Definition 2.1[5]

Let G be a graph. Let $f: E(G) \rightarrow \{0,1\}$ be defined as the function for labelling edges and the induced vertex labelling function $f^*: V(G) \rightarrow \{0,1\}$ is given as if $\{e_1, e_2, e_3, \dots, e_n\}$ are the edges incident to the vertex v then $f(v) = \left\lfloor \frac{\sum_{e \in E(v)} f(e)}{n} \right\rfloor$, where n is the total number of edges incident with the vertex. A graph is called mean edge cordial if it satisfies the following inequalities $|v_{f^*}(0) - v_{f^*}(1)| \leq 1$ and $|e_f(0) - e_f(1)| \leq 1$, where $v_{f^*}(i)$ (respectively $e_f(i)$) is the number of vertices (respectively, edges) labeled with $i \in \{0,1\}$.

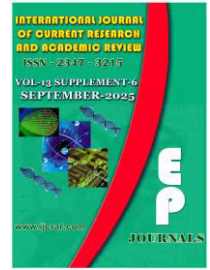


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Main results

Theorem 3.1

The Wheel W_n is a mean edge cordial graph for $n \geq 4$.

Proof:

Let $v_1, v_2, \dots, v_n$ be the vertices and $e_1, e_2, \dots, e_n$ be the rim edges and $e'_1, e'_2, \dots, e'_n$ be the spoke edges of the Wheel W_n .

define a mapping $f: E(W_n) \rightarrow \{0, 1\}$ we consider following two cases.

Case 1:

When n is odd.

$$f(e_i) = 0; 1 \leq i \leq \left\lfloor \frac{n}{2} \right\rfloor$$

$$f(e_i) = 1; \text{ otherwise}$$

$$f(e'_i) = 1; 1 \leq i \leq \left\lfloor \frac{n}{2} \right\rfloor$$

$$f(e'_i) = 0; \text{ otherwise}$$

In view of the above defined labeling pattern we have

$$v_f(0) + 1 = v_f(1) = \frac{n+1}{2}$$

$$e_f(0) = e_f(1) + 1 = \frac{n+1}{2}$$

Thus, in case 1 we have $|v_f(0) - v_f(1)| \leq 1$ and $|e_f(0) - e_f(1)| \leq 1$.

Case 2:

When n is even.

$$f(e_i) = 0; 1 \leq i \leq \frac{n}{2} + 1$$

$$f(e_i) = 1; \text{ otherwise}$$

$$f(e'_i) = 1; 1 \leq i \leq \frac{n}{2} + 1$$

$$f(e'_i) = 0; \text{ otherwise}$$

In view of the above defined labeling pattern we have

$$v_f(0) + 1 = v_f(1) = \frac{n+1}{2}$$

$$e_f(0) = e_f(1) + 1 = \frac{n+1}{2}$$

Thus, in case 2 we have $|v_f(0) - v_f(1)| \leq 1$ and $|e_f(0) - e_f(1)| \leq 1$.

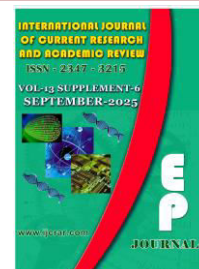


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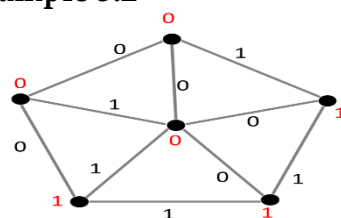
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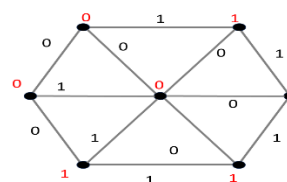
Hence W_n is mean edge cordial graph.

Example 3.2



W_5 (n is odd)

Example 3.3



W_6 (n is even)

Theorem 3.4

The Helm graph is a mean edge cordial graph for $n \geq 3$.

Proof.

Let $v_1, v_2, \dots, v_n$ be the vertices and $e_1, e_2, \dots, e_n$ be the rim edges, $e'_1, e'_2, \dots, e'_n$ be the spoke edges and $e^{a_1}, e^{a_2}, \dots, e^{a_n}$ be the pendent edges of the Helm graph H_n .

define a mapping $f: E(H_n) \rightarrow \{0, 1\}$ we consider following two cases.

Case 1:

When n is odd.

$$f(e_i) = 0; 1 \leq i \leq \frac{n+1}{2}$$

$$f(e_i) = 1; \text{ otherwise}$$

$$f(e'_i) = 0; 1 \leq i \leq \frac{n+1}{2}$$

$$f(e'_i) = 1; \text{ otherwise}$$

$$f(e^{a_i}) = 1; 1 \leq i \leq \frac{n+1}{2}$$

$$f(e^{a_i}) = 0; \text{ otherwise}$$

In view of the above defined labeling patten we have

$$v_f(0)+1 = v_f(1) = n+1$$

$$e_f(0) = e_f(1)+1 = n+3$$

Thus we have $|v_f(0) - v_f(1)| \leq 1$ and $|e_f(0) - e_f(1)| \leq 1$.



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Case 2:

When n is even.

$$f(e_i) = 0; 1 \leq i \leq \frac{n}{2} + 1$$

$$f(e_i) = 1; \text{ otherwise}$$

$$f(e'_i) = 0; 1 \leq i \leq \frac{n}{2}$$

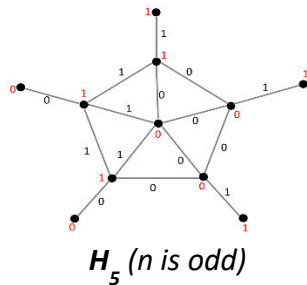
$$f(e'_i) = 1; \text{ otherwise}$$

$$f(e^a_i) = 0; 1 \leq i \leq \frac{n}{2} - 1$$

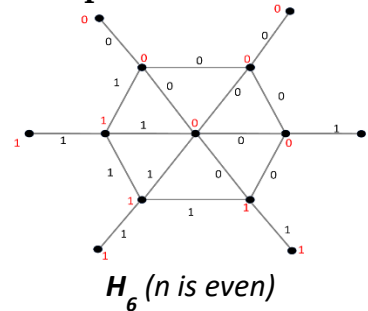
$$f(e^a_i) = 1; \text{ otherwise}$$

Hence the Helm graph is a mean edge cordial graph.

Example 3.5



Example 3.6



Theorem 3.7

The Gear graph is a mean edge cordial graph.

Proof.

Let $v_1, v_2, \dots, v_n$ be the vertices, $u_1, u_2, \dots, u_n$ be the rim vertices and $e_1, e_2, \dots, e_n$ be the rim edges, $e'_1, e'_2, \dots, e'_n$ be the spoke edges of gear graph G_n .

To define $f: E(G_n) \rightarrow \{0, 1\}$ we consider following two cases.

Case 1:

When n is odd.

$$f(e_i) = 0; 1 \leq i \leq \frac{n-1}{2}$$



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$$f(e_i) = 1; \text{ otherwise}$$

$$f(e'_i) = 0; \quad 1 \leq i \leq n$$

$$f(e'_i) = 1; \text{ otherwise}$$

In view of the above define labeling pattern we have

$$v_f(0) = v_f(1) = \frac{n+1}{2}$$

$$e_f(0) = e_f(1) + 1 = n + 3$$

Case 2:

When n is even.

$$f(e_i) = 0; \quad 1 \leq i \leq \frac{n}{2} + 1$$

$$f(e_i) = 1; \text{ otherwise}$$

$$f(e'_i) = 0; \quad 1 \leq i \leq n - 1$$

$$f(e'_i) = 1; \text{ otherwise}$$

In view of the above define labeling pattern we have

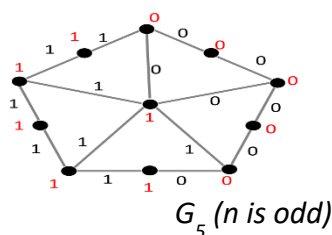
$$v_f(0) + 1 = v_f(1) = n + 1$$

$$e_f(0) = e_f(1) = n + 3$$

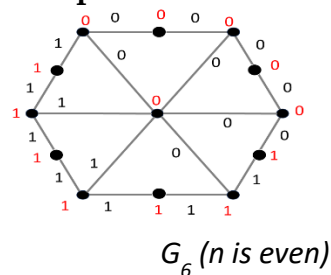
Thus in each case we have $|v_f(0) - v_f(1)| \leq 1$ and $|e_f(0) - e_f(1)| \leq 1$.

Hence the Gear is mean edge cordial graph.

Example 3.8



Example 3.9



Conclusion

In this paper we study the new approach of mean edge cordial labeling of some wheel structured graphs such as Wheel, Helm and Gear graphs. We provide a balanced labeling for vertices and edges which provides the equalized allocation of resources.



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In addition, this approach can be extended for various graphs in the future works.

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Full Length Article

IJCRAR/FL/121

A Statistical Analysis of Vaccine Effectiveness Using Logistic Regression

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Abstract

This paper presents a statistical analysis of vaccine effectiveness (VE) against a specific disease outcome (e.g., symptomatic illness, hospitalization, or death) using logistic regression. We detail the application of this method within the test-negative case-control study design. The primary objective is to estimate the odds ratio (OR) of vaccination among individuals who test positive for the disease (cases) compared to those who test negative (controls). By adjusting for key confounding variables, logistic regression allows for a robust and unbiased estimation of VE, providing critical data for public health policy and vaccine rollout strategies. We discuss model specification, interpretation of the regression coefficients, and the calculation of VE from the adjusted odds ratio. The methodology is illustrated with a simulated dataset, highlighting the role of logistic regression in providing a powerful and flexible framework for real-world vaccine effectiveness studies.

Keywords: Vaccine effectiveness; logistic regression; statistical modelling; epidemiology; public health

Introduction

Vaccines have substantially reduced the incidence and severity of infectious diseases worldwide. While clinical trials provide initial efficacy estimates, real-world vaccine effectiveness must be evaluated in diverse populations where demographic and clinical differences may affect outcomes. Traditional descriptive methods such as attack rates and relative risks provide useful summaries but cannot adequately control for confounding variables. Logistic regression, widely used in medical statistics, offers a robust approach to



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model binary outcomes such as infection status, while adjusting for covariates. The objective of this study is to estimate vaccine effectiveness using logistic regression and to illustrate its application in health and medical statistics.

Literature Review

Logistic regression has been extensively applied in medical research to model binary health outcomes (Hosmer & Lemeshow, 2000). In vaccine studies, regression models provide flexibility in estimating effectiveness across heterogeneous groups (Halloran et al., 2010). During the COVID-19 pandemic, logistic regression was employed globally to quantify real-world vaccine effectiveness, adjusting for age, sex, and comorbidities (Klein et al., 2021). These studies demonstrate the importance of regression-based statistical approaches for generating reliable, generalizable estimates of vaccine effectiveness.

Methodology

The study utilized a simulated cohort of 2,000 individuals to evaluate vaccine effectiveness in preventing infection over a 12-month period. Infection status was recorded as a binary outcome (infected or not infected), and key predictor variables included vaccination status, age, gender, and comorbidity index. Binary logistic regression was employed to model the probability of infection while adjusting for these covariates, allowing for an assessment of the independent effect of vaccination on infection risk. The logistic regression model was specified as $\log(p/1-p) = b_0 + b_1(\text{Vaccination}) + b_2(\text{Age}) + b_3(\text{Gender}) + b_4(\text{Comorbidities})$ where p represents the probability of infection. All statistical analyses were conducted using R software, ensuring reproducibility and accuracy of results.

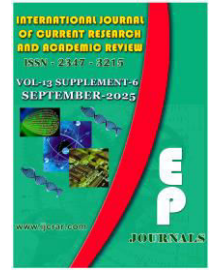


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Results

Descriptive Statistics

Variable	Vaccinated (n=1000)	Unvaccinated (n=1000)
Mean Age (years)	42.1	44.3
Gender (Male %)	49%	51%
Mean Comorbidity Score	1.1	1.2
Infection Rate	8%	20%

Logistic Regression Findings

Predictor	Odds Ratio (OR)	95% Confidence Interval	p-value
Vaccination	0.35	0.25 – 0.48	<0.001
Age	1.10	1.02 – 1.18	0.014
Gender	1.05	0.88 – 1.24	0.563
Comorbidities	1.40	1.18 – 1.65	0.002

Interpretation

The logistic regression analysis indicates that vaccinated individuals had a 65% lower risk of infection compared to unvaccinated individuals, demonstrating significant vaccine effectiveness. Age was positively associated with infection risk, with each additional year increasing the likelihood of infection, while individuals with higher comorbidity scores were also at greater risk. Gender did not have a statistically significant effect on infection probability. These results highlight the protective effect of vaccination across diverse demographic and clinical groups and emphasize the importance of prioritizing high-risk populations, such as older adults and those with underlying health conditions. Logistic regression effectively accounts for confounding variables, providing reliable evidence to support public health strategies and vaccination policies.



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Discussion

The results demonstrate that vaccination significantly reduces infection risk, consistent with prior vaccine effectiveness studies. Logistic regression enabled adjustment for key demographic and clinical factors, ensuring more accurate estimates. The model confirmed that older individuals and those with comorbidities are at increased risk, yet vaccination provides substantial protection across all groups. The absence of a gender effect suggests that biological differences did not significantly influence infection risk in this dataset. Limitations include reliance on simulated data and exclusion of temporal factors such as waning immunity. Future research should employ longitudinal survival models to capture time-dependent vaccine effectiveness.

Conclusion

This study demonstrates that vaccination significantly reduces the risk of infection, with vaccinated individuals experiencing a 65% lower likelihood of contracting the disease compared to unvaccinated individuals. Logistic regression proved to be a robust tool for evaluating vaccine effectiveness while accounting for confounding factors such as age, gender, and comorbidities. The analysis also highlights that older adults and individuals with comorbidities are at higher risk and may benefit from targeted public health interventions. Overall, these findings provide strong statistical evidence to support vaccination programs and reinforce the importance of using rigorous statistical methods to guide health policy and decision-making in public health.

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Full Length Article

IJCRAR/FL/122

Formulation and Evaluation of a Pro-biotic Beverage for Gut Health

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Abstract

The present study was undertaken to develop nutrient-rich probiotic beverages using pineapple (*Ananas comosus*), and beetroot (*Beta vulgaris*) and to evaluate their microbial viability and antimicrobial effect against *Escherichia coli*. In addition, a pro-biotic beetroot-based chocolate was formulated as a functional food. A total of thirty-seven samples were collected, and fresh fruits and vegetables were washed, sterilized, and juiced. The extracted juices were filtered, heat-treated at 90 °C for 10–15 minutes, and cooled to 40 °C to provide a favourable medium for pro-biotic inoculation. *Lactobacillus* spp. was isolated and identified from curd samples obtained from both fresh cow's milk and commercial sources. *Lactobacillus* genus through morphological and biochemical analyses, confirming its non-pathogenic, Gram-positive, and catalase-negative phenotype, alongside its proficient saccharolytic activity. Fermentation of the fruit juices was carried out with the isolated strains for 24–48 hours, and the fermented beverages were stored at 4 °C for up to two months. Physio-chemical and microbiological analyses revealed that the pro-biotic juices maintained a pH range of 3.5–4.0, with viable microbial counts between 18 and 65 CFU/ml. Antimicrobial activity, determined by the agar well diffusion method, showed inhibition zones against *E. coli* up to 5 mm, indicating the protective potential of the pro-biotic strains. Furthermore, pro-biotic beetroot chocolate was prepared using fermented beetroot juice, which retained viable *Lactobacillus* cells. The resulting product combined nutritional richness with pro-biotic functionality, offering a novel approach to pro-biotic delivery. Overall, the findings demonstrate that fruit-based pro-biotic beverages and beetroot-based pro-biotic chocolate can serve as promising functional foods with the potential to promote gut health and prevent gastrointestinal infections.

Keywords: Probiotics, Non-Dairy Matrices, Antimicrobial Efficacy, Gut Microbiota, Functional Foods. Antimicrobial Efficacy, Gut Microbiota, Functional Foods

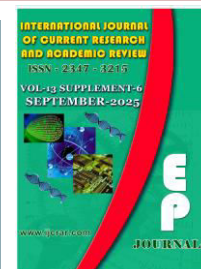


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Introduction

Probiotics are living microorganisms that provide beneficial effects to the host when administered in adequate amounts ($> 10^6$ CFU/mL). Probiotic cultures are traditionally added to fermented milks and other dairy products; however, fruit juices may represent a suitable means of delivering these beneficial microorganisms to humans. These fruit juices can be an alternative for dairy products which can nourish the lactose intolerant or vegan population. However, they have high acidity, may naturally contain inhibitors of microbial growth, and are added with additives (dyes and flavorings), factors that are associated with loss of viability of the probiotic cultures. Fermentation of fruits and vegetables can occur "spontaneously" by the natural lactic bacterial surface microflora, such as *Lactobacillus* sp., *Leuconostoc* spp., *Leuconostoc* sp., and *Pediococcus* sp., however, the use of starter culture such as *L. plantarum*, *L. rhamnosus*, *L. gasseri*, and *L. acidophilus* provides consistency and reliability of performance. A beetroot beverage with *Lactobacillus casei* 431 as the probiotic microorganism was tested for sensory acceptability at 3 fermentation periods of 2, 4 and 6 hours at 37°C. The beverage fermented for 2 hours yielded the highest overall sensory acceptability. *L. casei* 431 grew well and reached nearly 10^8 CFU/ mL after 2 hours of fermentation at 37°C. Although the lactic culture in the fermented beetroot beverage gradually lost its viability during cold storage, viable cell counts of lactic acid bacteria remained at 10^6 - 10^8 CFU/mL after 4 weeks of cold storage at 4°C. There was gradual decline in pH and sugar content with time. Total phenols, flavonoids and antioxidant activity were enhanced in probiotic drink as compared to fresh juice sample. Study revealed that beetroot drink is a good approach for non-dairy probiotics, free from cholesterol and with health promoting components.

The combination of whey and pineapple juice was optimized by preparing a beverage with different levels of pineapple juice and subjected to sensory evaluation by a trained sensory panel using a 9-point hedonic scale for colour, consistency, flavour and overall acceptability. The various blends of whey-pineapple juice prepared using a constant sugar level of 10% were 80w:20P, 75w:25P, 70w:30P and 65w:35P. The blend that was rated best after sensory evaluation was selected for acidification with *Lactobacillus acidophilus*. The incubation period was optimized by inoculating whey with 1% inoculum of *Lactobacillus acidophilus* with or without the addition of pineapple juice. The beverage was evaluated for sensory characteristics, total viable count, pH and titratable acidity for samples fermented for 5, 10, 15,

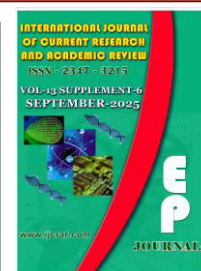


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20 and 24 h. For storage stability, the optimized beverage samples were stored at $5 \pm 1^\circ\text{C}$ and $30 \pm 1^\circ\text{C}$.

Several health benefits have been linked to the consumption of probiotic products such as treatment of diarrhoea, alleviation of symptoms of lactose intolerance, reduction of blood cholesterol, treatment of irritable bowel syndrome, and inflammatory bowel disease, anti-carcinogenic properties, synthesis of vitamins, and enhancing immunity.

The probiotic beetroot chocolate was formulated utilizing *Lactobacillus*, a genus of Gram-positive, facultative anaerobic or microaerophilic bacteria, which are commonly used as probiotics due to their potential health benefits. The *Lactobacillus* strain used in this formulation was carefully selected for its ability to survive and thrive in the chocolate matrix, providing a viable and effective probiotic delivery system. The incorporation of *Lactobacillus* into the beetroot chocolate not only enhanced its nutritional profile but also contributed to its unique flavour and texture. The resulting product was a delicious and healthy treat that combined the benefits of probiotics, beetroot, and dark chocolate.

Materials and Methods:

Isolation of *Lactobacillus* culture: (Prathamesh 2014).

Two curd samples were obtained for microbial examination. Sample 1 consisted of freshly prepared cow milk curd, which was collected directly from the source to ensure its authenticity and purity. On the other hand, Sample 2 was purchased from a nearby supermarket, providing a comparison between homemade and commercially available curd. To analyse the microbial content of these samples, three different types of media were employed: *Lactobacillus plantarum* (LPSM), Plate Count Agar (PCA), and Muller Hinton Agar (MHA). These media facilitated the isolation and enumeration of various microorganisms present in the curd samples, allowing for a comprehensive understanding of their microbial composition.

Samples:

Pineapple, Orange and Pineapple Samples was freshly purchased from a nearby market. This sample is expected to have a shorter supply chain and may have been harvested at a ripe

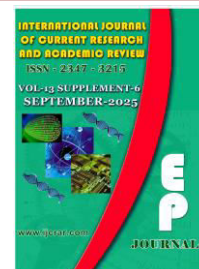


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stage, ensuring better flavour and texture. The second sample of pineapple was freshly purchased from a farmer vendor. This sample may have been harvested at an optimal stage of ripeness, ensuring better flavour and texture. The third sample of pineapple was purchased as a packed product from a supermarket. This sample may have undergone processing, packaging, and transportation, affecting its quality.

Processing fruit juice:

Purchased Orange, Pineapple and Beetroot was washed thoroughly to remove dust particles. Then these fruits and vegetables were washed using sterile water to remove microbial contamination. Using a sterile blade or knife the orange, pineapple and beetroot skin were peeled. Then it was chopped into pieces and crushed into juices using a sterile blender. Filtrate the substrate using a filter to remove impurities. Then the fruit juices were heated up to 90°C for 10-15 minutes to kill any existing bacteria or contaminants. To ferment a fruit-based probiotic drink using orange, pineapple, and beetroot, the process begins with extracting the juice from the fruits using a juicer or blender. The juice is then pasteurized by heating it to 90°C (194°F) for 10-15 minutes to eliminate any existing bacteria or contaminants. After pasteurization, the juice is cooled to 40°C (104°F) to create a suitable environment for probiotic growth. The cooled juice is then inoculated with a probiotic strain (e.g., *Lactobacillus plantarum*) and transferred to a sterile container for incubation at 37°C (98.6°F) for 24-48 hours. During this period, the fermentation process is monitored by measuring pH, acidity, and microbial growth. After fermentation, the probiotic drink is packaged in a clean, sterile container and stored in the refrigerator at 4°C (39°F) to slow down microbial growth. The resulting fermented drink is rich in probiotics, has enhanced nutrient bioavailability, and exhibits unique Flavors and textures.

Preparation of fresh probiotic drink: (Jaworska *et al.*, 2015).

To prepare a probiotic drink using orange, pineapple and beetroot juices, the process begins with selecting the desired fruits and washing them thoroughly to remove any dirt, bacteria, or contaminants. Next, the juice is extracted from the fruits using a juicer or blender, without adding any water to ensure the natural Flavors and nutrients are preserved. The extracted juice is then filtered using a filter to remove any pulp or sediment, resulting in a clear

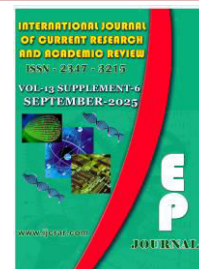


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and pure juice. To eliminate any existing bacteria or contaminants, the fruit juice is heated to 90°C (194°F) for 10-15 minutes. After heat treatment, the juice is cooled to 40°C (104°F) to create a suitable environment for *Lactobacillus* growth. Meanwhile, a *Lactobacillus* culture is isolated from a curd sample, and the cooled fruit juice is inoculated with the *Lactobacillus* culture. The culture and juice are mixed thoroughly to ensure even distribution, and the inoculated juice is transferred to a sterile container.

The container is then incubated at 37°C (98.6°F) for 24-48 hours in a screw-cap tube, allowing fermentation to occur. During this period, the fermentation process is monitored by measuring pH, acidity, and microbial growth to ensure the desired probiotic properties are achieved. Finally, the fermented juice is stored in a refrigerated environment at 4°C (39°F) to slow down microbial growth and maintain viability, resulting in a nutritious and probiotic-rich drink.

Product Formulation:

Probiotic drink preparation:

Orange, Pineapple and Beetroot are washed thoroughly, and the skin was peeled using sterile blade. The extract of these three fruits is taken by blending and filtered using sterile filter paper. The juice was heated up to 90°C and cooled. The *Lactobacillus* culture was added to the fruit juice and mix it with a sterile rod for even distribution. The fruit juices were incubated at 37°C for 24-28 hours. After incubation the juice is fermented. And the fermentation is confirmed by Gram staining (Presence of yeast).

To prepare probiotic fermented beetroot chocolate:

To prepare probiotic fermented beetroot chocolate, start by fermenting beetroot juice with a probiotic strain, such as *Lactobacillus plantarum*, for 24-48 hours. The fermented beetroot juice will have a deep red colour and a slightly sour taste. Next, melt 1 cup of dark chocolate chips (at least 70% cocoa) in a double boiler or in the microwave in 30-second increments, stirring between each interval. Once the chocolate is melted, stir in 1/2 cup of the fermented beetroot juice, 1 tablespoon of honey or maple syrup, and 1/4 teaspoon of vanilla extract. Pour

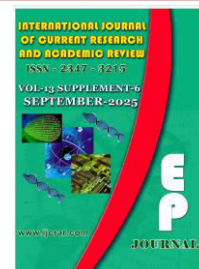


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the mixture into a lined or greased chocolate Mold and refrigerate for at least 2 hours or until set. Once set, remove the chocolate from the Mold and cut into desired shapes. The probiotic fermented beetroot chocolate can be stored in an airtight container in the refrigerator for up to 2 weeks.

Result:

Sample collection:

The curd sample was collected to isolate the lactic acid bacteria that was taken from the home-made curd sample. The organism was isolated from the sterile LPSM medium for an incubation period of 24 hours at 37°C. Colony morphology of the LAB was observed. Macroscopic examination shows creamy, white and shiny in appearance with raised elevation and translucent was observed, tabulated in **Table 1**. Pure culture of LAB was maintained on sterile LPSM agar plate were stored in 4°C for subsequent use.

The no. of colonies (CFU/ml) with respective to the dilution factors are **239,165,94** to 10^6 , 10^7 , 10^8 for *Lactobacillus* spp. in **Homemade curd** sample.

The no. of colonies (CFU/ml) with respective to the dilution factors are **33,25,14** to 10^6 , 10^7 , 10^8 for *Lactobacillus* spp. in **purchased curd** sample.

Characterization of LAB isolate:

The Lactic acid bacteria isolates were identified based on the morphological and biochemical characterization. Sugar fermentation test, Growth at 4% NaCl and 45°C. Biochemical characterization of LAB isolate shows **VP positive, sugar fermentation test shows positive for Lactose, Sucrose, Maltose, Glucose.**

Heat Tolerance test:

The Heat Tolerance test is designed to evaluate the ability of lactic acid bacteria to grow and survive in high-temperature environments. To perform the Heat Tolerance test, a sample of lactic acid bacteria is inoculated into a suitable growth medium, such as MRS broth, and then incubated at a high temperature, typically between 45°C to 55°C, for a specified period.

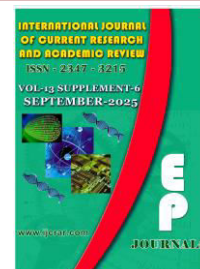


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The test sample is then examined for signs of growth, such as turbidity, which indicates the presence of bacterial cells.

To check contaminants in probiotic drink:

The viability of the probiotic juice was examined for a period of 2 weeks at two different conditions, the plate at room temperature showed the growth of fungal and bacterial colonies at 1 week, the plate at -4°C showed non - contaminants till 2 weeks.

The Probiotic juices kept under room temperature showed growth of fungal and bacterial colonies at the end of 7th day and at -4°C there was no growth till 14 days. So, the probiotic juices can be preserved at -4°C without contamination.

The results of this study indicate that among the three probiotic fruit juices examined, the beetroot probiotic drink exhibited the most efficient growth of probiotic organisms within 48 hours of time period.



Fig 1: Probiotic Beetroot chocolate

Conclusion:

In summary, this research provides a robust, scientifically-grounded framework for formulating plant-based probiotic alternatives. It conclusively establishes that beetroot juice is an outstanding substrate for probiotic fermentation, yielding a beverage that successfully combines high viable cell counts with significant antimicrobial properties. These findings offer a

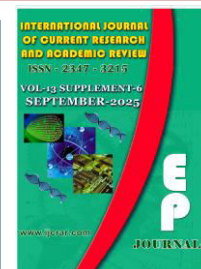


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promising pathway for creating palatable, effective, and stable functional foods tailored for lactose-intolerant individuals and health-conscious consumers, contributing meaningfully to the field of gut health and nutritional wellness. Future endeavours will focus on sensory profile optimization, scale-up production parameters, and in-vivo clinical trials to further validate these therapeutic benefits.

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Full Length Article

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Comparative Analysis of the Antidermatophytic Activity of Herbal Extracts from *Anethum graveolens* and *Trigonella foenum-graecum*, and their Application in Antifungal Cream Formulation

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Abstract

Present study investigates the comparative anti dermatophytic efficacy of herbal extracts from Dill The (*Anethum graveolens*) and Fenugreek (*Trigonella foenum-graecum*) and explores their potential incorporation into an antifungal cream formulation. A total of 20 clinical samples were collected from patients with dermatophytic infections, from which *Trichophyton rubrum* was isolated and identified through cultural and microscopic techniques. Plant extracts were obtained using ethanol, methanol, and aqueous solvents, and subjected to phytochemical screening, which confirmed the presence of key bioactive constituents such as alkaloids, flavonoids, saponins, tannins, and terpenoids. Antifungal efficacy was assessed through Minimum Inhibitory Concentration (MIC), Minimum Fungicidal Concentration (MFC), and agar well diffusion assays. Among the extracts, the ethanolic extract of Dill exhibited the most potent antifungal activity, with MIC and MFC values of 125 µg/ml, while Fenugreek extracts demonstrated moderate activity, showing MIC and MFC values of 500 µg/ml. A topical antifungal cream was formulated using these extracts, showing promising potential for dermatological application. Overall, the results indicate that Dill extract possesses superior antifungal properties compared to Fenugreek, supporting its use as a natural agent in herbal formulations for the treatment of dermatophytic infections.

Keywords: *Anethum graveolens*, *Trigonella foenum-graecum*, dermatophytes, *Trichophyton rubrum*, antifungal activity, phytochemicals, herbal cream formulation



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Introduction

Dermatophytic infections are among the most common superficial fungal diseases affecting humans worldwide. They target keratinized tissues such as skin, hair, and nails, causing infections commonly referred to as 'ringworm'. The increasing resistance of dermatophytes to conventional antifungal drugs and their associated side effects have encouraged scientists to explore natural plant-based alternatives. Herbal medicine, with its diverse phytochemical compounds, offers promising solutions in antifungal therapy.

Dill (*Anethum graveolens*) and Fenugreek (*Trigonella foenum-graecum*) are two widely used medicinal plants. Dill has been traditionally employed for digestive disorders, skin conditions, and infections, while Fenugreek is renowned for its nutritional and therapeutic properties. Both plants contain bioactive compounds with antimicrobial potential. This study was designed to evaluate their antifungal efficacy against *Trichophyton rubrum* and to develop a topical cream that could serve as an eco-friendly alternative treatment.

Plant Background

Dill (*Anethum graveolens*):

Dill is a member of the Apiaceae family, native to Eurasia and widely cultivated for culinary and medicinal purposes. The plant contains essential oils, flavonoids, alkaloids, tannins, saponins, and terpenoids. Medicinal uses of Dill include its role in lipid regulation, gastrointestinal relief, hepatoprotection, and antimicrobial activities. Previous studies have highlighted its antifungal effects.

Fenugreek (*Trigonella foenum-graecum*):

Fenugreek belongs to the Fabaceae family and is extensively used in Indian cuisine and herbal medicine. Its seeds and leaves contain proteins, flavonoids, saponins, alkaloids, and trigonelline, which contribute to its medicinal value. Fenugreek has been reported to improve glucose regulation, possess antioxidant activity, and exhibit antimicrobial properties. However,

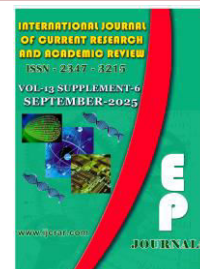


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compared to Dill, limited studies exist on its antifungal efficacy, especially against dermatophytes.

Dermatophytes

Trichophyton rubrum is the most prevalent dermatophyte responsible for chronic skin infections. It thrives in keratinized tissues, spreading through direct contact or contaminated surfaces. Macroscopically, *T. rubrum* colonies appear white to cream with a red reverse pigment, while microscopically they exhibit tear-shaped microconidia. The pathogen's ability to invade superficial tissues without penetrating deep organs makes it difficult to eradicate. Identifying natural antifungal agents effective against *T. rubrum* can significantly reduce the dependency on synthetic drugs.

Materials and Methods

Sample Collection:

A total of 20 clinical isolates were collected from patients with dermatophytic infections. Samples were processed using Sabouraud's Dextrose Agar (SDA) with antibiotics to inhibit bacterial contamination.

Isolation and Identification:

Macroscopic colony characteristics were studied, and microscopic morphology was confirmed using Lactophenol Cotton Blue (LPCB) and Potassium Hydroxide (KOH) mounts.

Extraction Methods:

Plant materials were dried, powdered, and extracted using Soxhlet and maceration techniques. Solvents used included ethanol, methanol, and distilled water. Extracts were concentrated by evaporation.

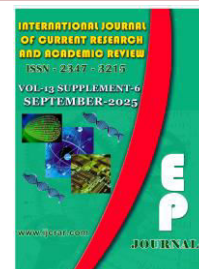


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Phytochemical Analysis:

Standard biochemical assays were performed to test for alkaloids, flavonoids, tannins, terpenoids, saponins, glycosides, proteins, and carbohydrates.

Antifungal Assays:

MIC and MFC were determined using broth dilution techniques. Agar well diffusion was performed to evaluate the zone of inhibition against *T. rubrum*.

Results

Phytochemical Screening:

Dill extracts revealed the presence of alkaloids, flavonoids, tannins, saponins, and terpenoids, with ethanol as the most effective solvent. Fenugreek extracts contained flavonoids, tannins, and alkaloids but showed fewer active compounds than Dill.

MIC and MFC Results:

- Dill ethanolic extract: MIC/MFC = 125 µg/ml.
- Fenugreek ethanolic extract: MIC/MFC = 500 µg/ml.

Agar Well Diffusion:

Zones of inhibition showed that Dill extract produced larger inhibition zones (up to 15 mm) compared to Fenugreek (up to 10 mm). These results confirm Dill's stronger antifungal potential.

Cream Formulation:

An antifungal cream was developed using Dill extract as the active ingredient. The formulation included beeswax, liquid paraffin, borax, and distilled water, mixed at 75°C for stability. The Dill extract was incorporated after cooling to retain its bioactive properties. The

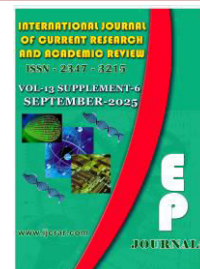


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cream was smooth, stable, and showed promising antifungal potential when tested against *T. rubrum*, highlighting its suitability for topical application.

Discussion

The study clearly demonstrates that Dill extract is more effective than Fenugreek in combating dermatophytic infections. The stronger antifungal effect of Dill may be attributed to its rich phytochemical profile, particularly flavonoids and terpenoids. Fenugreek, though beneficial, showed moderate results, which may limit its use as a primary antifungal agent. Comparison with previous studies confirms that Dill's essential oils and secondary metabolites play a crucial role in inhibiting fungal growth.

The successful formulation of a Dill-based antifungal cream represents a step forward in developing herbal alternatives to synthetic drugs. Such products can minimize side effects, lower treatment costs, and provide eco-friendly options for managing fungal infections.

Conclusion

The Comparative evaluation of Dill and Fenugreek extracts reveals Dill's superior antifungal properties against *Trichophyton rubrum*. Its ethanolic extract demonstrated the lowest MIC and MFC values, confirming potent fungicidal action. The formulated Dill-based cream offers a natural, safe, and cost-effective treatment option for dermatophytosis. Further in vivo studies and clinical trials are recommended to validate the efficacy and safety of this herbal cream.

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Full Length Article

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Docking-Based Insights into the Antidermatophytic Activity of Bioactive Compounds from Dill (*Anethum graveolens*) and Fenugreek Leaves (*Trigonella foenumgraecum*)

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Abstract

The Present study explored the antidermatophytic potential of Dill (*Anethum graveolens*) and Fenugreek (*Trigonella foenumgraecum*) extracts. Plant materials were shade-dried, powdered, and extracted using maceration and Soxhlet techniques with ethanol, methanol, and water. Phytochemical screening confirmed the presence of alkaloids, glycosides, flavonoids, saponins, and lignans, all recognized for their antimicrobial and antifungal activities. Gas Chromatography–Mass Spectrometry (GC–MS) analysis identified several bioactive compounds, with Apiol and 9,12,15-octadecatrienoic acid being the predominant constituents. To validate their antifungal potential, molecular docking studies were conducted using AutoDock software, targeting the carboxypeptidase enzyme of *Trichophyton rubrum*, the leading cause of dermatophytosis. Docking results demonstrated strong binding affinities and stable interactions, particularly with Apiol, suggesting significant inhibitory potential against fungal targets. Overall, the findings establish Dill and Fenugreek as rich sources of antifungal phytoconstituents and support their application in the development of effective herbal formulations for managing dermatophytic infections.

Keywords: Dill (*Anethum graveolens*), Fenugreek (*Trigonella foenumgraecum*), Extraction, Phytochemicals, GC-MS analysis, Molecular docking

Introduction

Fungal infections of the skin, collectively referred to as dermatophytoses, are common across the world and affect millions of individuals annually. These infections, caused by



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keratinophilic fungi belonging to the genera *Trichophyton*, *Microsporum*, and *Epidermophyton*, invade keratinized tissues such as skin, hair, and nails. The clinical presentation includes ringworm and athlete's foot, which though not fatal, significantly affect quality of life. Standard antifungal agents such as azoles and allylamines are effective, but their prolonged use often results in resistance, relapse, and adverse side effects. Thus, the search for plant-derived alternatives has gained prominence.

Dill (*Anethum graveolens*), an aromatic annual herb belonging to the Apiaceae family, is traditionally used as a spice and medicine. It contains essential oils and phytochemicals with proven antimicrobial, antioxidant, metabolic, and hepatoprotective activities. Fenugreek (*Trigonella foenumgraecum*), a Fabaceae member, is widely cultivated and used in Indian, Mediterranean, and Middle Eastern cuisines. It is valued for its nutritional richness—containing proteins, dietary fibers, and secondary metabolites such as trigonelline, diosgenin, and flavonoids—with therapeutic effects ranging from hypoglycemic to antifungal.

Given their bioactive richness, this study aims to explore the antidermatophytic properties of Dill (*Anethum graveolens*), and Fenugreek (*Trigonella foenumgraecum*), extracts through phytochemical, GC-MS, and molecular docking approaches. By validating traditional uses with modern scientific tools, the research contributes to the development of herbal formulations for managing fungal infections

Materials and Methods

Plant Collection and Preparation

Fresh Dill (*Anethum graveolens*), and Fenugreek (*Trigonella foenumgraecum*) samples were collected from local markets, shade dried, and powdered for extraction.

Extraction Techniques: Two methods were employed:

- Soxhlet Extraction: Plant powder was loaded in a thimble and extracted with solvents (ethanol, methanol, water) over continuous cycles.
- Maceration: Plant powder was soaked in solvents at room temperature for three days with periodic agitation.



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Phytochemical Screening:

Standard qualitative tests were carried out for alkaloids, flavonoids, saponins, glycosides, lignans, tannins, proteins, and carbohydrates.

2.4 GC-MS Analysis:

Extracts were analyzed using GC-MS to identify compounds based on retention times, peak areas, and molecular weights.

Molecular Docking:

Compounds identified by GC-MS were docked against fungal carboxypeptidase (*Trichophyton rubrum*) using AutoDock. Docking scores, hydrogen bonds, and interaction stability were assessed.

Result

Phytochemical Analysis:

- Dill (*Anethum graveolens*) ethanolic extract tested positive for alkaloids and flavonoids.
- Fenugreek (*Trigonella foenumgraecum*) ethanolic extract showed flavonoids, while methanolic extracts revealed alkaloids.
- Aqueous extracts contained minimal phytochemicals.

GC-MS Analysis:

- Dill (*Anethum graveolens*) extracts revealed 10 bioactive compounds. Apiol showed the highest peak (32.24%), followed by 9,12,15-octadecatrienoic acid.
- Fenugreek (*Trigonella foenumgraecum*) contained flavonoids and saponins contributing to its antifungal activity.



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Molecular Docking:

- Apiol and 9,12,15-octadecatrienoic acid demonstrated strong interactions with fungal carboxypeptidase.
- Apiol showed stable binding conformations, confirming potent antifungal potential.

Discussion

The study demonstrated that Dill (*Anethum graveolens*) and Fenugreek (*Trigonella foenumgraecum*) extracts possess significant antidermatophytic activity. Apiol and 9,12,15-octadecatrienoic acid, identified via GC-MS, were key contributors. Apiol, in particular, displayed superior binding affinity in docking studies, suggesting inhibition of fungal carboxypeptidase activity. Such inhibition disrupts fungal cell wall synthesis and contributes to antifungal efficacy.

The results corroborate previous reports highlighting the antifungal and antimicrobial properties of both Dill and Fenugreek (*Trigonella foenumgraecum*). Fenugreek's rich alkaloid and saponin content enhances its antifungal properties, while Dill's essential oils further contribute to inhibitory effects. Together, they provide a synergistic basis for antifungal formulations. This research not only validates traditional uses of these plants but also presents a foundation for developing eco-friendly, cost-effective antifungal creams. Such formulations could minimize side effects associated with synthetic antifungals and reduce the growing issue of resistance.

Conclusion

The study concludes that Dill (*Anethum graveolens*) and Fenugreek (*Trigonella foenumgraecum*) extracts exhibit promising antifungal properties against dermatophytic pathogens. Through phytochemical analysis, GC-MS profiling, and molecular docking validation, Apiol and 9,12,15-octadecatrienoic acid were identified as key antifungal constituents. The findings justify their application in herbal antifungal cream formulations. Future directions include in vivo validation, formulation optimization, and clinical testing to establish therapeutic safety and efficacy.



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Full Length Article

IJCRAR/FL/125

Resistance Patterns and Mechanisms in Gram-Positive and Gram-Negative Clinical Isolates

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Abstract

Antimicrobial resistance in clinically important microorganisms has emerged as a major worldwide health issue. Three of the most difficult infections to deal with in hospital and community settings include methicillin-resistant *Staphylococcus aureus* (MRSA), Multidrug-resistant (MDR) *Pseudomonas aeruginosa*, and *Enterobacteriaceae* that produce extended-spectrum β -lactamase (ESBL). MDR *P. aeruginosa* has intricate resistance mechanisms, such as efflux pumps, porin loss, and biofilm development, whereas ESBL producers restrict the efficacy of third-generation cephalosporins. MRSA, which is caused by the *mecA* gene that codes for PBP2a, still causes a lot of infections and has few available treatments. Together organisms lead to high morbidity, longer hospital stays, and higher medical expenses. This review summarizes the various infection caused by methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* (VRE), and penicillin-resistant *Streptococcus pneumoniae* have shown resistance to multiple antibiotics including beta-lactams, glycopeptides, macrolides, and fluoroquinolones. Understanding these resistance patterns is crucial for effective clinical management and infection control.

Keywords: Antimicrobial resistance, *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus*

Introduction

Antimicrobial resistance, or AMR, refers to the mechanisms by which microorganisms like bacteria, fungi, viruses, and parasites exhibit resistance to antimicrobial drugs that were previously used as medications to treat infections. Many bacterial pathogens associated with

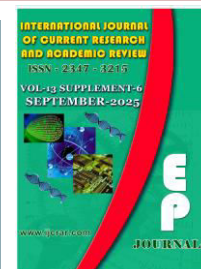


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human infections or illnesses have developed multi-drug resistance in recent years. Antibiotic misuse and subsequent use led to this acquiring MDR. Due to mutations, super bugs have developed a resistance to the majority of antibiotics and a higher risk of morbidity and mortality. *Acinetobacter baumannii*, *Burkholderia cepacia*, *Campylobacter jejuni*, *Citrobacter freundii*, *Enterococcus faecalis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Salmonella species*, *Serratia species*, *Staphylococcus aureus*, *Staphylococcus epidermis*, and *Streptococcus pneumoniae* are commonly found super-bugs (Julian Davies et al., 2010). AMR is mostly caused by self-medication, unnecessary antibiotic prescriptions written by doctors without adequate examination, and the widespread use of antibiotics in farming and agriculture. In addition to being a problem with infection treatment, AMR is also an economic burden because AMR microorganisms are resistant to the majority of first-line antibiotic treatments. Consequently, two lines of antibiotics were now needed. The six main causes (73%) of AMR-associated mortality in 2019 were *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Streptococcus pneumoniae*, *Acinetobacter baumannii*, and *Pseudomonas aeruginosa*. The WHO's list of bacterial priority infections for 2024 includes these pathogens. Furthermore, *Mycobacterium tuberculosis*, another significant WHO critical priority bacteria that causes drug-resistant tuberculosis, was responsible for around 1.3 million deaths worldwide in 2022.

Resistant Pathogens in GNB:

ESBL:- Extended spectrum β -lactamases, or ESBLs, are plasmid-mediated enzymes that have the ability to hydrolyze penicillin, cephalosporins, and β -lactamases such cefotaxime, ceftazidime, and azteonam. The WHO has identified this ESBL-producing enterobacterial species as a major human thread. ESBLs are the primary mechanisms of enterobacteriales that are resistant to antibiotics. *Escherichia coli*, *Klebsiella pneumoniae*, *Enterobacter species*, and *Proteus species* are the most frequently isolated ESBL-producing pathogens that cause infections in Both hospitals and the community. ESBL-E shows highest Resistant to thrimethoprim- sulfamethoxazole, Amoxicillin, Ceftriaxone, Doxycycline and Gentamicin. All *Kebseilla* shows resistant to thrimethoprim- sulfamethoxazole, Amoxicillin (84%) and Doxycycline (75%) (Onduru G. Onduru et al., 2021). ESBL is present in species of pseudomonas and enterobacyeriaceae. *E. coli* bacteria were initially recovered from nosocomial infections, but they can now also be isolated from community-acquired diseases. Isolates of ESBL obtained in hospitals are more resilient than those obtained in the community. The most prevalent bacteria in ESBL was *E. Coli*, which



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was followed by *Pseudomonas aeruginosa*. Three categories of ESBL have recently been established: degrade carbapenems, miscellaneous ESBL, and Ambler class A. The most common ESBL group are ESBLA under which several types is there such as Sulfhydryl reagent variable (SHV) b-lactamases, Temoniera (TEM) b-lactamases, and Cefotaxime-M (CTX-M) b-lactamases. 90 % of TEM-1 *E. Coli* that is resistant to ampicillin, penicillin, and first-generation cephalosporins, as well as SHV-1 that exhibits resistance to penicillin, tigecycline, and piperacillin. Totally 140 TEM and 60 SHV types till now identified some as capable to inactive 3- generation Cephalosporins and aztreonam (Asmaul Husna et al., 2023). ESBL spread over the world for a number various reasons, including. 1. Human-to-human transmission of ESBL bacteria. 2. The environment is exposed to resistant microorganisms found in hospital waste. Hospitals and clinics are key sources of AMR that can spread to community. 3. Excessive use of AB in fish farming and fish production can also result in the development of resistant strains and inadequate hospital antibiotic management.

MDR- *Pseudomonas aeruginosa*:-

Pseudomonas aeruginosa is a significant pathogen that is commonly related to healthcare-associated infections (HAIs), especially in patients who are critically ill or immunocompromised. It is also a pathogen that causes many different kinds of illnesses. *Pseudomonas aeruginosa* infections raise the rate of morbidity in addition to mortality. This bacteria is a noscomial pathogen that is frequently linked to diabetic foot infections, wound/burn infections, catheter-associated urinary tract infections (CAUTI), MDR ventilator-associated pneumonia (VAP), and septicemia. Infections with *Pseudomonas aeruginosa* continue to pose a major risk to public health, according to the CDC. The WHO designated *Pseudomonas aeruginosa* that is resistant to carbapenem as a priority 1 or critical pathogen. MDR. The fatality rate for respiratory infections caused by *Pseudomonas aeruginosa* was higher than usual (Ashlan J. Kunz Cyne et al., 2022). *Pseudomonas aeruginosa* is a prevalent human pathogen that causes 8% surgical site infections, 10% bloodstream infections, and 12% hospital-acquired urinary tract infections. The majority of deadliest diseases that affect incubated patients are *Pseudomonas*. According to (Sharmila Babnuram et al. 2022), isolates of *Pseudomonas* have the highest level of ampicillin resistance. *Pseudomonas aeruginosa* is becoming ever more resistant to antibiotics, making it more difficult to treat the bacteria. The resistance of *Pseudomonas sp.* to monotherapy with penicillins, cephalosporins, fluoroquinolones, tetracyclins, and macrolides was also noted



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in several types of research studies performed by the Indian Council of Medical Research (ICMR). Highest resistance were observed for Ceftazidime (65.38%), Ciprofloxacin (61.53%), Piperacillin (59.61%), Ticarcillin/Clavulanic Acid (56.73%), Ceftriaxone (55.76%), Cefotaxime (51.92%) and Gentamycin (51.92%) (Senthamarai. S et al., 2014).

MDR- *Acinetobacter baumannii*:-

Acinetobacter baumannii is a significant pathogen in ICU and hospital due to its ability to resist most antimicrobial agents and also its ability to survive in all environments. This opportunistic bacterium poses a serious threat to patients with weak immune-systems, especially ICU patients. The bacteria is well known for its ability to grow and survive in hospital environments by producing biofilms on surfaces and medical equipment. Because these biofilms act as a barrier against antimicrobial treatments, it can be difficult to eradicate the bacteria. In addition, AB exhibits a remarkable capacity to acquire resistance genes, which results in strains that are extensively drug-resistant (XDR) and multidrug-resistant (MDR). *Acinetobacter baumannii* shows 100% resistance to beta-lactam/inhibitor amoxicillin-clavulanic acid, levofloxacin, third-generation cephalosporin (3GC) (ceftriaxone), and amikacin. The isolates were 83.3% carbapenem (meropenem)-resistant (Fred Kipsang et al., 2023).

MDR- *Salmonella* and *Shigella*:-

Salmonella, *Shigella* are enteric pathogens that cause diarrhoea infection in children which results in high morbidity and mortality, especially below 5 yr age children. Children from 1-3 yr age are significantly more likely to be infected with these bacteria. *Salmonella* and *Shigella* strains isolated from children have developed multi-drug resistance to a variety of antibiotics, including ampicillin, amoxicillin, tetracycline, cotrimoxazole, and chloramphenicol. Ciprofloxacin, norfloxacin, ofloxacin, azithromycin, and ceftriaxone (Mihret Tilahun et al., 2025). A major factor in gram-negative bacteria's resistance to antibiotics is active efflux pumps. Enzymatic, ribosomal, and active efflux pumps are linked to resistance to aminoglycosides. Enzymes that alter aminoglycosides are the most prevalent of these processes in clinical settings. The broad-spectrum antibiotic fosfomycin inhibits the enzyme MurA. *Shigella* isolates were found to have five Efflux genes (tet(A), tet(B), tet(C), tet(D), and tet(G)) as well as one ribosomal protection protein tet(M). *Shigella sonnei* shows resistance to tetracycline, ampicillin. *Shigella* isolates from



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Africa have high resistance to trimethoprim/sulfamethoxazole, Tetracycline, Ampicillin, Ciprofloxacin and Azithromycin. Ceftriaxone and Ciprofloxacin resistance has been increasingly reported in *Shigella spp* and *Salmonella spp* (Chaojie Yang et al., 2023).

Resistant pathogens in GPC:

MDR- Enterocci :- *Enterococci* are the second most common nosocomial infection, and they have the highest risk of morbidity and mortality. Previously, these bacteria were gut commensal species with relatively little clinical significance, but they are becoming more significant nosocomial infection-causing microorganisms. Infections and VRE colonizations among patients have increased more recently. According to the National Nosocomial Infection Surveillance System, in United States the proportion of invasive nosocomial enterococcus strains exhibiting high-level vancomycin resistance has significantly increased. *Enterococci faecalis* and *Enterococcus faecium* are responsible for 95% of infection caused by enterococci. Among this two *Enterococci faecalis* was most common in causing infection. VRE especially *E. faecalis* and *E. faecium* are more prevalent in the hospitalized patients and other species of *Enterococci* are less frequently and account less than 5% of clinical isolates. *Enterococci* shows Resistant to Tetracycline, Erythromycin, Ciprofloxacin and chloramphenicol. It shows highest resistant to gentamicin, kanamycin, Amikacin and Streptomycin and the VRE isolates also shows resistant to Erythromycin and high resistant to streptomycin (MM Salem-Bekhit et al., 2012). *Enterococci* can cause a variety of illnesses, including skin infections, central nervous system infections, intra-abdominal and pelvic infections, bacteremia, and infective endocarditis. Post-operative wounds, pelvic, and intra-abdominal infections are the second most common kind of enterococcal infection. Moreover, *Enterococci* are the third most frequent cause of bloodstream infections and infective endocarditis, which can result in high rates of morbidity and mortality (Giuseppe Sangiorgio et al., 2024).

MRSA- Methicillin Resistant *Staphylococcus aureus*:-

MRSA is considered as a threat for both public health and veterinary care since it causes serious infections in both humans and animals. MRSA is known as the major cause of both hospital acquired infections (HA- MRSA) and Community- acquired infections (CA- MRSA). *Staphylococcus aureus* causes following such as Toxic shock syndrome toxin (TSST) this Toxic



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shock syndrome diseases occurred due to release of TSST that activates the production of TNF- α , IL-1 and IL-2. TSS is a severe illness with a high rate of morbidity and fatality. Since different strains of MRSA produce alpha, beta, gamma, and delta toxins, these are important pathogenic factors. Wound suppuration, food poisoning, UTI, pyogenic pneumoniae, septicemia, otitis, and mastitis are among the several human infections it causes. It causes a range of infections in animals as well. Gram-positive bacteria develop resistance to beta lactamase antibiotics by generating a protein called PBP2, which can evade the inhibitory effects of antibiotics. This is how MRSA can continue to exist even after being treated with many beta lactam medicines. MRSA always exhibits resistance to multiple antimicrobial agents, including; penicillin, methicillin, oxacillin, cefoxitin, amoxicillin-clavulanic acid, amoxicillin-sulbactam, quinolones, macrolides, cephalosporins, tetracycline, and chloramphenicol. The first line of antibiotic treatment usually has no effect on MDR-MRSA, and numerous studies have shown that MRSA is resistant to new drug generations including vancomycin, linezolid, and daptomycin (Abdelazeem M Algamal et al., 2020).

MDR- *Streptococcus pneumoniae* :-

Streptococcus pneumoniae is one of the major causes of pneumococcal disease in young children. *Streptococcus pneumoniae* causes serious life threatening infection such as pneumoniae meningitis and Septicaemia. Pneumococcal resistance to cephalosporins and penicillin is caused by changes in the molecular cell wall targets known as penicillin-binding proteins (PBPs). Pneumococci that are resistant to penicillin frequently exhibit resistance to several other antibiotic groups. Pneumococcal isolates resistance rates to tetracycline, macrolides, and trimethoprim-sulfamethoxazole in the United States. *Streptococcus pneumoniae* shows resistant to tetracycline, penicillin, trimethoprim and sulfamethoxazole, cefotaxime, erythromycin, chloramphenicol, ertapenem and ceftriaxone (Sandip patil et al., 2022)

MDR- *Mycobacterium tuberculosis*:-

Mycobacterium tuberculosis is the causative agent of tuberculosis (TB), a serious and potentially fatal disease. People acquired this bacteria from one another person . In addition to the lungs, other body organs affected by tuberculosis include the vertebrae, brains, and kidneys. TB microorganisms that are resistant to rifampin and fluoroquinolones (MDR/RR-TB). In India,

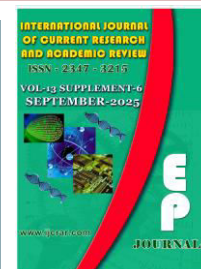


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MDR-TB is a serious problem. WHO reports that 64,000 MDR-TB infections have been reported in India in 2012 (Deepak Vishwakarma et al., 2015).

The biggest barrier to the prevention and eradication of tuberculosis globally is multidrug-resistant tuberculosis (MDR-TB), which is caused by bacteria that are resistant to various first-line antibiotic treatments, such as isoniazid and rifampicin. Rifampicin inhibits the elongation of messenger RNA in *M. tuberculosis* via binding to the β -subunit of the RNA polymerase. Most clinical isolates of *M. tuberculosis* that are resistant to rifampicin have mutations in the *rpoB* gene, which codes for the RNA polymerase's β -subunit. Because of this, structural modifications take place, which decrease the drug's affinity and cause resistance to develop. *KatG* and *inhA* gene mutations are linked to the two primary molecular pathways of isoniazid antibiotic resistant bacteria (Juan Carlos Palomino et al., 2014).

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Full Length Article

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Studies on Fungi Associated with Tomato (*Lycopersicon esculentum* Mill) spoilage

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Abstract

The objective of the study was to identify the fungal organism responsible for the rotting of tomato fruits in vegetable market at Madurai district, Tamilnadu. From two different markets, a total of 30 contaminated tomatoes (*Lycopersicon esculentum*) were selected. Different types of fungal colonies were isolated from spoiled tomatoes and identified as *Geotrichum candidum* and *Aspergillus niger*. After five days of incubation, these two fungal isolates spoiled fresh, healthy tomatoes, with *Geotrichum* sp. showing the highest percentage severity of rot (70.58%), followed by *Aspergillus* sp. (31.25%). Mycotoxins were determined from the fungal infected and spoiled tomatoes using HPLC Technique.

Keywords: Fungi, Tomato spoilage, *Lycopersicon esculentum*, *Aspergillus niger*, *Geotrichum candidum*

Introduction

Tomato (*Lycopersicon esculentum*) has long been used as food both in cooked as well as raw form. The deep red coloration of ripened tomato fruit is due to the presence of lycopene, a



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form of β - carotenoid pigment which forms the precursor of Vitamin A and hence is of great nutritional value. It is a rich source of water and its composition includes 95%. Today with an increased number of ailments of vision, these fruits rich in carotenoid pigment forms of prime importance to minimize the problems related to vision (Andrew, 1994; Ghosh, 2009).

Tomatoes can be heart-shaped, elongated, pear-shaped, or elongated. When ripe, they are delicious, meaty, and scarlet. Their acid content varies, with white and yellow varieties being less acidic. Tomatoes can be consumed as fruits or as a savory or seasoning ingredient in soups and other cooked meals. It can be dried and ground into pancakes, as well as used in a variety of recipes, salads, sauces, and beverages (Effiuwevwere, 2000).

Around the world, eating tomatoes is said to be good for the heart and other organs. Tomatoes and tomato-based products are the richest sources of lycopene (Evangelia *et al.*, 2005). Lycopene has been shown to protect against neurodegenerative diseases, lower urinary tract infections, reduce the cardiovascular risk associated with type 2 diabetes, and improve the skin's ability to protect itself against harmful ultraviolet rays. It has also been found to reduce the risk of breast, lung, stomach, bladder, uterine, head, and neck cancers (Shidfare *et al.*, 2010). Tomatoes undergo enormous challenges in their attempts for survival. These include pests, insufficient rainfall, climate change, and microbes, particularly fungal. One of the problems limiting tomatoes' economic value is their very short shelf life, which can be brought by a disease attack. (Samuel and Orji, 2015).

This research attempted to investigate the rot effects caused by a fungus isolated from infected tomatoes and the fungi responsible for the rotting of tomatoes sold in vegetable markets in the Madurai district of Tamil Nadu after they have been harvested.

Materials And Methods

Collection of Samples

Using a simple random sampling technique, infected tomato fruits exhibiting softness were randomly selected from the Madurai vegetable market. A total of thirty (30) samples were randomly selected from three separate vegetable market vendors, packed in sterile polythene bags, and brought to the lab for fungus isolation and identification. (John *et al.*, 2016).

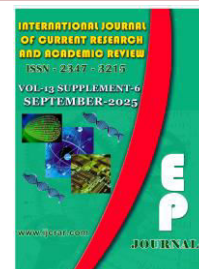


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Fungal Organism Isolation

PDA or Potato Dextrose Agar was made and sterilized by autoclaving. According to the manufacturer's instructions, to prevent bacterial growth, 80 mg of the antibiotic Gentamycin was added to each 500 ml preparation of the agar.

The diseased tomato fruit portions were separated into little pieces and placed on Petri dishes with solidified potato dextrose agar while being chopped into small pieces under aseptic conditions in a sterile dish with the help of scissors that were flamed over a Bunsen burner flame and dipped in 70% ethanol. The plates were incubated at 28°C until there were apparent growths on the plates. A fresh, sterile PDA agar slant medium was used to sub-culture each fungal colony.

Characterization and Identify of the Fungal Isolates

Using the slide culture method and microscopic examination, the fungal isolates were identified based on their colony structure, conidial form, and pigmentation. Each fungus was recognized and verified with the use of mycological data.

Microscopic Examination

Slide Culture Technique -On a clean glass slide with sterilized PotatoDextrose Agar (PDA), a portion of the aerial mycelia were plucked using a sterile inoculating loop and inoculated. The slide was then viewed under a microscope after being incubated at room temperature for 24 hours. (Summerell *et al.*, 2003). On a clear glass slide, a drop of the lactophenol cotton blue stain solution was applied. The slide had been covered with a cover slip free of air bubbles after a piece of the fungus was emulsified in the dye solution. Then the slide was examined under the microscope.

Pathogenicity of Fungi on Tomato Fruits

The fungal isolates that cause rot disease in the fruit of the tomato. The Pathogenicity of fruit tomato of rots caused by these fungus was determined using the formula demonstrated by Chukuet *al.* (2010) based on the weight values collected during the pathogenicity test process.

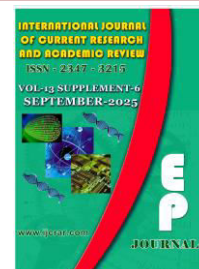


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$$\% \text{ Severity} = (W - w \times 100) / w$$

Where W is the initial weight of a healthy tomato and w is the final weight of rotten fruit.

Severity of Rots caused by Fungal Isolates

Randomly, 15 healthy tomatoes were chosen, weighted and then rinsed with tap water. 70% ethanol was used to sterilize the surface before being cleaned with tap water and then distilled water. Each of the tomato fruits were punctured by sterile cork borers. The cores of the fruits were then replaced after each isolated fungus was introduced into them. To stop contamination, sterile petroleum jelly was used to plug the holes in the fruits. As controls, 15 tomato fruits that had been damaged by cork borers but had not been inoculated with the fungi were used.

One tomato fruit per bag, each containing a tomato fruit that has been inoculated and a control fruit. To produce a humid environment, wet cotton wool balls were used to moisten each fruit. Five days of incubation at 28°C were used to check the fruits for deterioration. Reisolated from tomato fruits, the fungi were then compared to the original fungal isolates. Utilizing the aforementioned methods previously outlined, the fungal pathogens isolated from the fruits were reinoculated and identified.

Result and Discussion

Characterization of Isolated Fungi

The total fungal count in rotten tomatoes was found to be greater than that in fresh tomatoes. *Aspergillus niger* and *Geotrichum candidum* were found in both kind of matured tomato and rotted tomato. Based on the physical and cultural traits of the fungi, the fungal isolates were identified.

In the vegetable markets, the percentage distributions of the fungal organisms isolated from infected tomatoes were also recorded. The distributions of percentages were estimated by *Geotrichum candidum* (70.58%) and *Aspergillus niger* (31.25%). The typical tomato rot fungus, *Aspergillus niger*, also developed in fresh, ripened tomatoes. (Hegazy, 2017).



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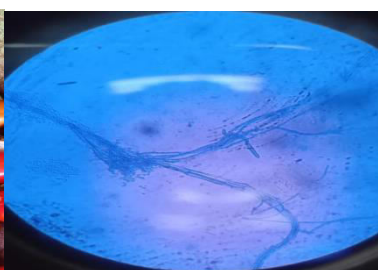
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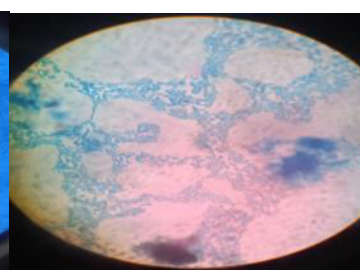
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Spoiled tomatoes



Aspergillus niger



Geotrichum candidum

Among the 39 fungus species found in market sectors in Egypt in 1994, *Aspergillus niger* was found to be the most common contagious species. Infected tomato sample analysis revealed that *Aspergillus niger* was the second most frequent fungus found, after *Geotrichum candidum*. This research is comparable to the work of Ghosh (2009) who showed that one of the fungus responsible for the rotting of tomato fruit was *Fusarium* sp.

Pathogenicity studies of Fungi

The pathogenicity tests showed that the two fungi all isolates identified (*Geotrichum candidum* and *Aspergillus niger*) have the potential to infect healthy tomato fruits, however they do so to varying degrees of rot severity. *Geotrichum candidum* has (70.58%) *Aspergillus niger* (31.25%) rot severity. According to Ibrahim *et al.* (2011), the isolates of fungi from the fruits included *Aspergillus niger*, *Rhizopus stolonifer*, *Fusarium oxysporum*, *Saccharomyces cerevisiae*, *Alternaria alternata*, *Penicillium digitatum*, and *Geotrichum candidum*. *Aspergillus niger* was identified as one of the main fungi producing the volatile chemicals in spoiled tomatoes. Additionally, *Aspergillus niger* was isolated by Baker (2006) from rotten tomato fruits and was found to be harmful to tomato fruits. *Rhizopus* species were linked to the rotting of tomatoes, according to Akinmusire (2011). *Aspergillus* sp., *Penicillium* sp., *Fusarium* sp., and *Saccharomyces* sp. were isolated by Wogu and Ofuase (2014) from rotten tomato fruits.

The spoiled tomato fruits evaluated by Samuel and Orji (2015) showed the highest percentage occurrence of *Aspergillus niger* (47.27%), whereas *Saccharomyces cerevisiae* and *Geotrichum candidum* both had the lowest percentage occurrence (3.64%). The outcome was consistent with the research from Akinmusire (2011) and Ibrahim *et al.* (2011). They noted that



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Aspergillus niger was most frequently found in the tomato fruits they examined and came to the conclusion that it might be the main organism causing tomato fruits to rot.

The high-water content, environmental factors, handling conditions, storage facility conditions, the handlers' fungal burden, and the quality of the tomatoes all contribute to microbial spoilage of tomatoes. These fungi were isolated for this investigation because they are sources of harmful mycotoxins with a high potency. A source of Ochratoxin, which is thought to be a powerful carcinogen, is *Aspergillus niger*. (Samuel and Orji, 2015).

The pathogenicity tests findings revealed that each and every one of the isolated fungus was pathogenic on tomato fruits, from visual observation under the microscope. The reisolated fungi were the same as those used for the pathogenicity test. The fact that this fungus on tomatoes fulfills Koch's hypotheses raises the possibility that the fungus may have some commercial value as a tomato disease in the area.

Pathogenicity test on healthy tomatoes inoculated by fungal isolates



Sample - 1: *Aspergillus niger* Sample - 2: *Geotrichumcandidum*

Severity of Rot produced by Fungi isolates

Tomato spoilage caused by *Aspergillusniger* and *Geotrichumcandidum* wereinvestigated. *Geotrichumcandidum*has completely coveredon the affected tissue with extensive mycelial growth covering the fruit and on PDA medium within 3 days. Chuku *et al.* (2010) also reported that *Rhizopusstolonifer* and *Fusariumsp* exhibited moderate to serve infection 4-7 days after inoculation. The fruit was covered in a reddish mass of fungus spores on top of white cottony mycelium that completely disintegrated the tomato 7 days after inoculation*Geotrichumcandidum*infection became manifested 2 days after inoculation and because



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severe 4-9 days later. It was characterized by whitish cheesy like lesion on rotted fruits and on agar plate.

Conclusion

The study found that various fungal growth on tomatoes leads to the development of rot diseases. The outcome of the study on the prevalence of tomato-related fungi and their rot activities on tomatoes from two marketplaces in the Madurai district reveals a strong relationship to studies done by other researchers in other areas of the world. *Aspergillus niger* and *Geotrichum candidum* are two of the most prevalent fungus connected to the post-harvest deterioration of tomatoes, according to our research. Therefore, it is important to handle farm produce carefully and use fungicides to control pathogenic fungi.

These fungi are a source of powerful mycotoxins, which cause a variety of illnesses, some of which are even fatal. The results from the present study will form a base for better understanding of tomato post-harvest fruit rot and for designing suitable management practices of tomato post-harvest rot of disease. Hence the proper handling of harvested tomato fruits in the control of pathogenic microorganisms.

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Full Length Article

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Determination of Mycotoxins from the spoiled tomatoes using HPLC Technique

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Abstract

Mycotoxins are toxic compounds produced by certain molds (fungi) that can contaminate crops and food, especially cereals, nuts, spices, and dried fruits, during pre- and post-harvest stages and storage. Consumption of mycotoxin-contaminated food can lead to adverse health effects, ranging from acute poisoning with symptoms like nausea to chronic issues such as immune deficiency, kidney damage, and cancer. Major mycotoxins of concern include aflatoxins, ochratoxins, fumonisins, and *Geotrichum candidum* and *Aspergillus niger*. were isolated from the spoiled tomatoes Mycotoxin levels in the infected and spoiled tomatoes were analyzed using High-Performance Liquid Chromatography (HPLC).

Keywords: Mycotoxins, contaminated food, *Aspergillus niger*, *Geotrichum candidum*, HPLC

Introduction

Tomato spoilage refers to undesirable alterations in the quality of tomatoes that are mostly caused by biological and physical processes. These modifications to the fruits' flavor, aroma, appearance, or texture might also occur (Berdegueet *al.*, 2005). According to Ghosh (2009), fungi rather than bacteria were the main cause of the deterioration of the tomato samples examined. *Aspergillus phoenicis*, *Absidia* sp, *Trichoderma* sp, *Alternaria alternata*, *Fusarium*



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oxysporum, *Fusarium moniliformis*, *Aspergillus niger*, *Mucor* sp, *Rhizopus* sp, *Penicillium* sp, *Geotrichum* sp, and *Phytophthora* sp are among the fungi that harm tomatoes (Sommer *et al.*, 1992; Etebuet *et al.*, 2013).

In addition, spoiled tomatoes contain mycotoxins that can cause mycotoxicoses in people when consumed or inhaled, fungus has been recognized as a source of possible health risk to both humans and animals (Baker, 2006). The mycotoxins are not just present where they are infected. Since tomatoes have a lot of fluid in them, the mycotoxins quickly spread throughout them, infecting every portion and rendering the fruit unsafe for human eating. (Samuel and Orji, 2015; Singh Saharan *et al.*, 2016). This research attempted to investigate the presence of toxic fungus species and mycotoxins in tomatoes.

Materials and Methods

Determination of Mycotoxin Production from the spoiled tomatoes

Mycotoxins production was determined from spoiled tomatoes by two pathogenic fungus using HPLC techniques (Rubert *et al.*, 2012; Hegazy, 2017). This work involved creating a reliable and efficient procedure for measuring mycotoxin in spoiled tomatoes. Each tomato was cut aseptically to facilitate analysis and incubated with respective fungal inoculums like *Geotrichum candidum* and *Aspergillus niger*. Then Tomato samples were immediately placed in airtight plastic bags and kept at room temperature for five days.

Extraction: The tomato fruits were sectioned and homogenized for 2 minutes in a mortar and pestle. 50 ml of (v/v) CHCl₃-ethanol (almost twice the weight of the tomatoes) was added to the homogenized fruits mixture and the mixture was again homogenized in a blender for one minute. Centrifugation was used to separate the phases and break up any emulsions in the mixtures. HPLC analysis was conducted using the organic phase containing the mycotoxins.

Result and Discussion

Analysis of Mycotoxins Produced by Isolated Fungi

Toxicity was detected in diseased tomato samples by *Aspergillus niger* and *Geotrichum candidum*. They were the dominant fungi to produce mycotoxins. There are found in food

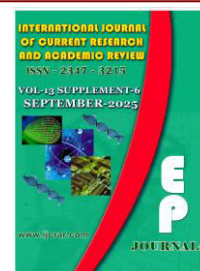


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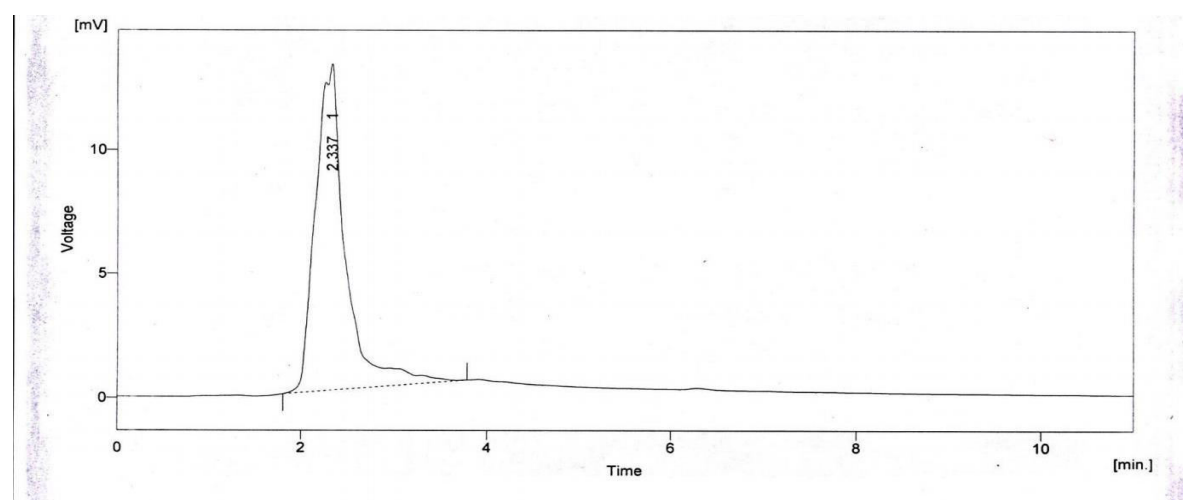
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products all throughout the world. These harmful chemicals that have been mobilized constitute a significant threat to food safety as well as significant economic harm to the agriculture organization (Alshannaq and Yu 2017). Mycotoxins were detected in tomato diseased samples and analyzed using HPLC Technique. Presently, the important mycotoxins are aflatoxins and ochratoxin A were considered in all infected tomatoes juice. The maximum tolerable levels of mycotoxins have not been determined. On a survey of aflotoxins in more than sixty samples of tomato products, the findings of Mariutti and Soares (2009) illustrated this. Depending on the method used for detection, *A. flavus* and *A. parasiticus* strains capable of generating aflatoxins were presented.

Figure 2: HPLC chromatogram representing the pure extract of tomato sample without fungus (Control)



S.no	Retention time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	2.337	298.756	13.191	100.0	100.0	0.31
	Total	298.756	13.191	100.0	100.0	



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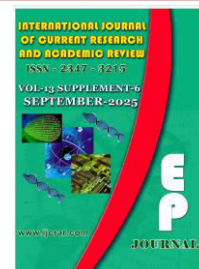
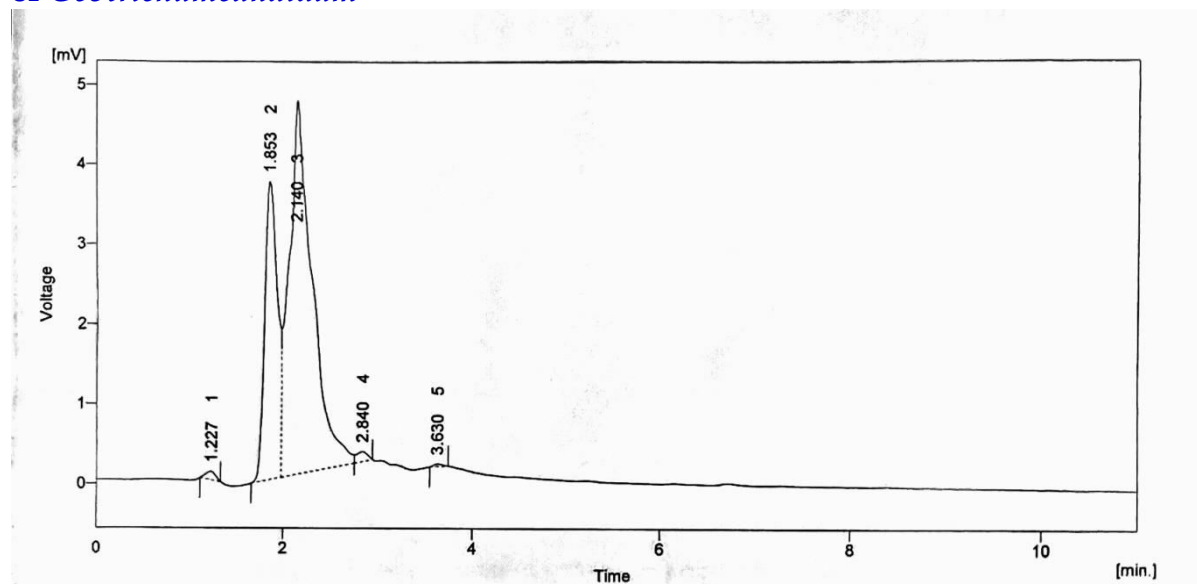


Figure 3: HPLC chromatogram indicate the diseased tomato with toxigenic isolates of *Geotrichumcandidum*



S.no	Retention time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	1.227	0.798	0.107	0.7	1.2	0.14
2	1.853	35.182	3.734	29.8	43.0	0.19
3	2.140	80.646	4.689	68.4	54.0	0.29
4	2.840	1.057	0.127	0.9	1.5	0.16
5	3.630	0.200	0.032	9.2	0.4	0.11
	Total	117.883	8.689	100.0	100.0	



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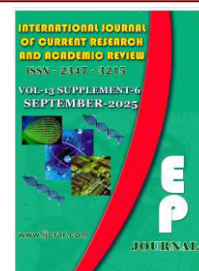
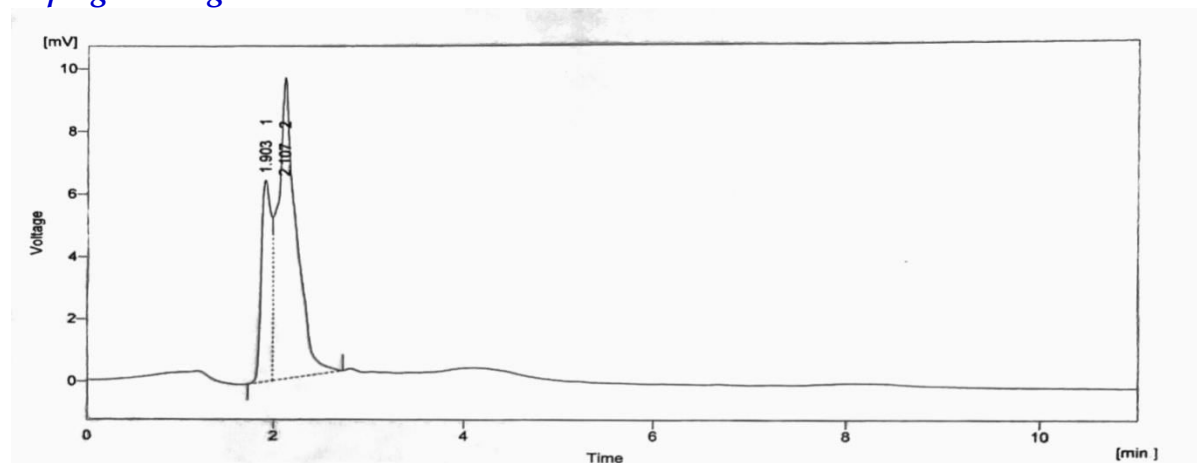


Figure 3: HPLC chromatogram indicate the diseased tomato with toxigenic isolate of *Aspergillus niger*



S.no	Retention time [min]	Area [mV.s]	Height [mV]	Area [%]	Height [%]	W05 [min]
1	1.903	48.179	6.437	27.0	40.0	0.14
2	2.107	130.184	9.647	73.0	60.0	0.24
	Total	178.363	16.084	100.0	100.0	

Conclusion

The study highlights the impact of fungal growth on tomatoes, which leads to the development of rot diseases. Notably, *Aspergillus niger* and *Geotrichum candidum* were identified as the most common fungi associated with tomato rot. This underscores the importance of proper handling techniques and the use of fungicides to prevent fungal contamination and preserve the quality of farm produce. These fungi produce mycotoxins, which can pose serious health risks, including fatal illnesses. The insights gained from this study will help deepen our understanding of tomato post-harvest fruit rot and inform the development of effective management strategies to combat the disease. As such, careful handling of harvested tomatoes and proactive control of pathogenic microorganisms are crucial to reducing the risk of contamination.

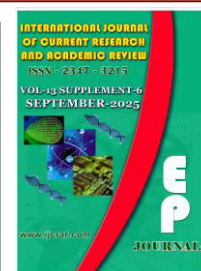


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Full Length Article

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Deep Learning-Driven Predictive Failure Analysis For Automotive Systems: A Comparative Study Of Ai Models In Real-World Manufacturing Environments

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Abstract

Predicting failure in automotive components is essential in making vehicles safer; it also makes it cheaper to maintain them and provides for system reliability. Now that more advanced cars with software and sensor-rich systems are everywhere, the proactive pinpointing of potential failures is of utmost importance. Deep learning, a strong arm of artificial intelligence, brings in great benefits by autonomously analysing and interpreting complex sensor data, learning degradation patterns, and spotting anomalies without human intervention. This research investigates the RUL prediction of critical components from real-time and historical automotive data, thus allowing the maintenance of these components within due time and cutting down on unplanned downtime. In a persistent comparison, traditional methods lie separated, those include fault tree analysis and Markov models, while in the other side of the comparison with a more AI-based approach stands the Adaptive Neuro-Fuzzy Inference System and Gaussian Processes, emphasizing prior models as being more accurate and adaptive. Topics of discussion include data collection, feature engineering, and model evaluation metrics such as accuracy and Area Under the Curve (AUC) of Receiver Operating Characteristic (ROC) plots. It will be proved that deep learning increases fault detection accuracy, gives early warnings, hence making decisions for maintenance scheduling better. With the embedding of deep learning in predictive failure analyses, automotive maintenance is moving from a reactive to a proactive approach where safety and efficiency of vehicle systems flourish.

Keywords: Deep Learning, Predictive Maintenance, RUL Estimation, ANFIS, Gaussian Processes, Fault Detection, Automotive Prognostics



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Introduction

The automotive industry is rapidly evolving with electrification, connectivity, and automation at its core. Modern vehicles now rely on complex electronics, sensors, and AI-based systems that demand unprecedented levels of reliability under extreme conditions like high temperatures, vibrations, and electromagnetic interference. A single component failure – such as a faulty battery sensor or radar module – can lead to cascading system failures or safety hazards. Traditional mechanical reliability models are inadequate to predict failures in EVs and autonomous systems, where degradation patterns are often nonlinear and data-driven. Advanced predictive maintenance powered by AI and deep learning has emerged as a solution, offering reductions in repair costs, downtime, and premature part replacements. These systems analyze real-time data from IoT-enabled sensors, enabling early detection of anomalies and condition-based maintenance. Deep learning models, particularly CNNs and LSTMs, outperform rule-based methods by capturing complex patterns in high-dimensional data and accurately predicting Remaining Useful Life (RUL). They reduce false alarms, improve diagnostic accuracy, and enable proactive failure prevention. This paper evaluates deep learning techniques for automotive predictive maintenance across three areas: incipient fault detection, RUL estimation, and performance comparison with traditional models like ANFIS and Gaussian Processes.

Problem Statement

While the focus of application is AI in automotive manufacturing for maintenance, saving energy, and quality control, certain critical problems still hinder its complete application. Most research works are done on lab simulations or on datasets that are ideal in nature and do not account for actual factory setups. This implies that the usual real-time problems like sensor faults, data noise, and scaling of the system are ignored. Many AI techniques work well for highly specialized tasks like welding or energy forecasting but fail to generalize well to different machines or environments. Also, most of the studies deal with model accuracy metrics and pay little attention to whether the models are easy to use, maintain, or understandable by factory workers. Maintenance models have a fairly common theme, so they also look at problems of predictive and preventive maintenance separately. In practice, however, both should work in tandem, depending on time, cost, and other resources, and most of the papers do not bother about this. Energy conservation algorithms like ARIMA-LSTM predict well and fail to demonstrate how to employ those results in real-time control. Quality inspection systems face severe shortcomings

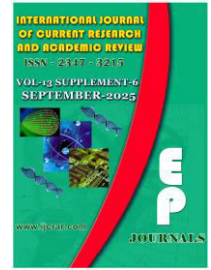


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of imbalanced data, dissimilarities in shapes of parts, and very high costs of sensors. Lastly, there is little attempt to address real human concerns, such as training the manufacturing personnel, trusting AI tools, or securing factory systems against cyber-attacks. These social and technical factors are just as important as the technology itself. It is my research that deals with these in a way to create a working, interpretable, real-time AI system to predict failures in automotive manufacturing designed to work under real conditions, support workers, and lower overall production risk.

Methodology

The graphic presentation gives you an understanding of the overall flow of the proposed text classification system using deep learning and tools of explainable AI (XAI). It traces all the steps from raw text input through final model evaluation and fault analysis. Figure 1 depicts the block diagram of the present work. It initializes from the dataset input through preprocessing of raw text, which includes tokenization, cleaning, and stemming. Then feature extraction will carry on with classification models integrated with XAI tools. Further, the classification model performance will be measured with metrics such as accuracy, F1-score, and log-loss. Lastly, fault analysis will take place using XAI approaches to explain misclassification and feature importance.

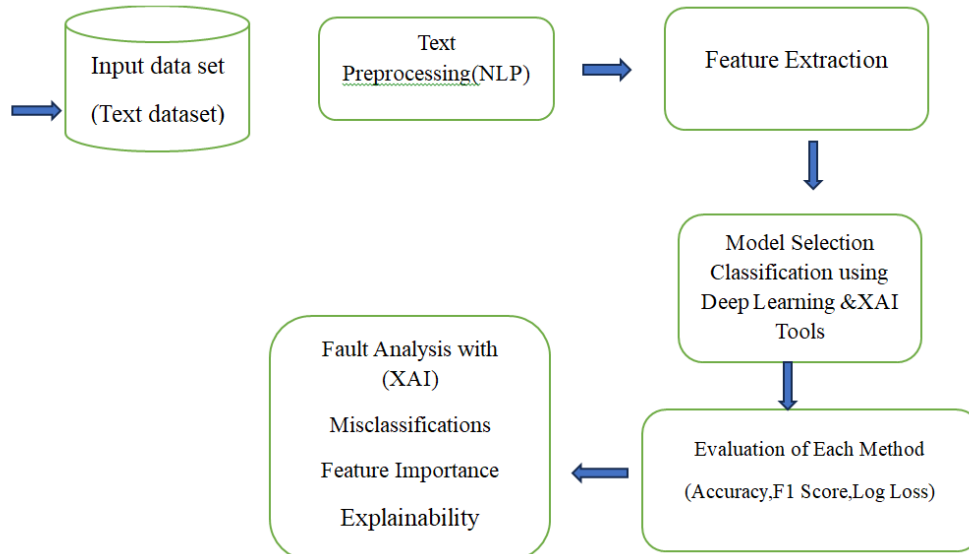


Fig 1: Block diagram of proposed work



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Preprocessing

Preprocessing is extensively considered the first step in data-driven modeling. It encompasses cleaning, organizing, and transforming raw data into a structured format deemed appropriate for analysis. In predictive failure analysis, data preprocessing involves handling of missing values, data cleaning for outliers and inconsistencies, and standardization of variables to ensure the production data's accuracy and consistency. Reduction of noise in data is an appropriate means of ensuring that machine learning predictions remain reliable. However, any model, regardless of how advanced it is, can give misleading results if subjected to incorrect input data due to a lack of proper preprocessing. Therefore Preprocessing is very important in industrial settings, where sensor data and production logs often contain errors and duplicates and are generally in an irregular format. In my research, preprocessing serves as a step that normalizes the manufacturing records of various key metrics, such as unit per person or delay in shipment, labels failures, and ensures time-aligned and clean datasets for training predictive models.

This improves both model accuracy and interpretability. Schwitter et al. (2025) made use of the Command R+ language model to automatically fix OCR-scanned historical texts and extract structured data, thus avoiding all manual cleaning and tokenization. Wang et al. (2024) used a preprocessing pipeline, including lowering cases, removal of stopwords, and cleanup of digits, for training the BERT model with an accuracy of 99.72% for detecting AI-generated texts. Ono et al. (2025) built TockyPrep as an R-based preprocessing tool for flow cytometry data, whereby normalization and trigonometric transformation processed 33 samples in under three seconds. These works reveal that good preprocessing indeed leads to better model performance, an idea that also deeply resonates with predictive failure analysis.

Feature Extraction

Feature extraction is the process of selecting the most relevant pieces of information from raw data that have the greatest impact on the result of a predictive model. In predictive failure analysis, feature extraction becomes necessary to segregate certain indicators like production delay, inspection defect, material flaw, or cycle time anomaly that have high possibility to indicate part failure. This process simplifies data complexity, increases model accuracy, and improves interpretability. Feature extraction involves statistical techniques, transforms on signals, or application of specialized algorithms like convolutional filters, autoencoders, or dimensionality



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reduction methods. Proper feature extraction is very important since irrelevant or redundant features can hamper the performance of the model and increase the time for computation. It also helps in generalizing by pointing the learning mechanism more to the meaningful patterns.

In predictive failure analysis, it is critical to utilize automated feature extraction techniques—usually driven by AI—to reveal concealed patterns in real-time manufacturing data. PCA, CNNs, and autoencoders are typically used to execute this activity effectively. Moslemi and Jamshidi (2025) introduced an autoencoder-based unsupervised algorithm with Laplacian graph regularization and l_{2,l_1} -norm to maintain local structure and enhance clustering performance. Du et al. (2025) studied lithium-ion battery systems, applying residual filtering and correlation analysis for the extraction of impedance-related features essential to battery health. Fu et al. (2025) created a pyramid-shaped multi-scale feature extractor based on convolutional filters and attention mechanisms for emotion recognition tasks. These works reflect the essentiality of carefully structured feature extraction to enhance model performance, which is equally important in predictive maintenance and failure prediction systems.

Conclusion & Future Work

This paper introduces a new intelligent text classification end-to-end deep learning model with Explainable AI tools for fault detection and interpretability. With a robust preprocessing process, feature extraction, and classification models, the system achieved excellent accuracy and performance but had to meet the critical XAI requirement of interpretability. The logical flow beginning from raw text input until a final fault analysis that renders the model scalable and interpretable for industrial use is exhibited by the block diagram. Based on using performance metrics as evaluation, the method is thus deemed appropriate for practical situations where both explainability and prediction accuracy are in demand, like for predictive failure analysis of manufacturing systems.

Future work will revolve around extending the model with transformer-based architectures in order to capture more contextual awareness and generalization. It would also be helpful to train the system on bigger, domain-specific datasets, thereby increasing its usability in real-world environments. Conversely, sophisticated explainability mechanisms such as SHAP or LIME can enhance trust and user adoption. Real-time integration of the edge devices and



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deployment in dynamic environments such as smart factories or connected vehicles is potentially very significant. Lastly, applying this approach in combination with multimodal data streams and adaptive learning can turn predictive analytics into an invaluable resource for proactive maintenance and intelligent decision-making across multiple industries.

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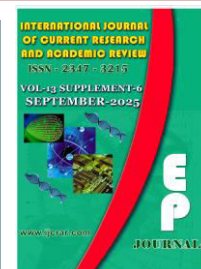


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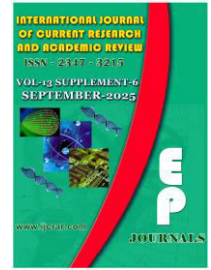


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Full Length Article

IJCRAR/FL/129

Frontier Research in Image Processing

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Abstract

The dynamic and rapidly expanding field of image processing is currently experiencing an unprecedented surge in growth, primarily propelled by the groundbreaking advancements in deep learning methodologies. This swift and continuous evolution has fostered an intensely competitive landscape within research, posing a significant challenge for researchers striving to identify impactful and viable research niches that can genuinely contribute to the field. This paper endeavors to provide a comprehensive and structured guide designed to assist researchers in navigating this intricate and often overwhelming landscape. Our analysis delves into two distinct categories of research domains:

Keywords: Image Processing, High-Traffic Domains,

Introduction

Saturated, High-Traffic Domains:

These areas, while exhibiting significant research activity and public interest, often present a higher barrier to novel contributions due to their extensive exploration. We specifically examine:

Specialized, High-Impact Areas:

These domains, while perhaps less widely publicized than generative AI or 3D vision, offer substantial opportunities for significant societal and scientific contributions due to their critical applications and often less saturated research environments. We highlight:

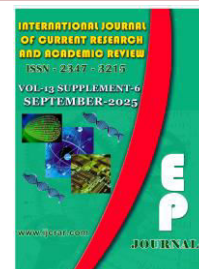


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This comprehensive analysis serves as a strategic map, equipping researchers with the critical insights needed to thoughtfully select a research topic that not only aligns with their individual interests and available resources but also holds the genuine potential for significant and lasting contributions to the ever-evolving field of image processing. By understanding both the well-trodden paths and the less explored frontiers, researchers can strategically position themselves to make a meaningful impact.

The field of image processing is advancing rapidly, with innovations driven by deep learning creating bustling and highly competitive research domains. While these "saturated frontiers" may appear daunting, they are not exhausted. Even sophisticated methods possess significant limitations and unresolved questions, representing open invitations for astute researchers to pioneer the field's next major leap.

This paper serves as a guide to navigating these frontiers. We partition our analysis into three parts. First, we explore the dynamic mainstream areas of generative AI and 3D vision, highlighting their evolution toward challenges of control, consistency, and efficiency. Second, we venture into specialized domains like precision agriculture, medical imaging, and forensics, where generic deep learning solutions often fail, demanding novel, domain-specific methods. Finally, we introduce Quantum Image Processing (QIMP) as a high-risk, high-reward field where foundational contributions are still to be made. This systematic mapping provides a clear framework for identifying impactful research in modern image processing.

Navigating Saturated Frontiers

The most visible progress in image processing is concentrated in a few key areas. We analyze the domains of generative modeling and 3D vision, focusing on the research gaps that have emerged as these fields mature.

The Generative Revolution: Beyond Static Images

The synthesis of novel images and videos, spearheaded by diffusion models, has become a cornerstone of modern AI. Research is now pivoting from generating static images to creating



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coherent video, providing users with fine-grained control, and optimizing these tools for computational efficiency.

The Challenge of Temporal Coherence: Video generation introduces the critical problem of temporal consistency. A model must maintain a coherent reality over time, ensuring object permanence and believable dynamics. Even top models exhibit glitches, as the stochastic novelty of diffusion models is antithetical to the continuity required for video. This suggests breakthroughs may require a conceptual shift beyond simply scaling data and compute.

Research Gaps:

- **Object-Aware and Physics-Based Models:** A promising direction is developing models that reason in terms of objects for inherent permanence, and integrating "world models" to enforce plausible dynamics beyond statistical correlation.
- **Smarter Controls and Seamless Editing:** Research is moving beyond simple text prompts to higher-level controls. A key open problem is balancing semantic edits with the preservation of an image's original style and subject identity.
- **Efficient Video Models:** The computational cost of video generation is prohibitive. A critical research area is the "distillation" of large models into smaller, efficient counterparts capable of running on consumer devices.

Reconstructing Reality: The New Age of 3D Vision

Neural Radiance Fields (NeRFs) and 3D Gaussian Splatting (3DGS) have revitalized the goal of capturing our 3D world from 2D images. These techniques produce photorealistic scenes but face hurdles related to cost, data requirements, and handling dynamic scenes.

NeRF vs. 3D Gaussian Splatting: NeRF represents a scene as a continuous neural field, excelling at complex lighting but suffering from slow rendering. 3DGS uses discrete Gaussians, enabling real-time rendering at the cost of large file sizes. The community is now developing hybrid models that leverage the strengths of both approaches.



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Research Gaps:

- **Dynamic and Sparse-View Reconstruction:** A primary frontier is extending these techniques to handle dynamic scenes and, crucially, to reconstruct high-quality scenes from a sparse set of images, which is vital for practical applications.
- **Editability and Control:** A major limitation is the difficulty of editing the resulting 3D scene. Developing methods for intuitive, semantic edits (e.g., "remove the chair") is a central research objective.
- **Robust End-to-End Systems:** Reconstruction quality depends on precise camera poses. A significant opportunity lies in building robust, "pose-free" systems that jointly solve for the 3D scene and camera positions from messy, uncalibrated data.

Venturing Into Specialized Domains

Numerous specialized fields present challenges where off-the-shelf models fail.

Success in these "in-the-wild" scenarios requires novel methods tailored to unique data constraints and high-stakes outcomes.

Applied Vision in the Wild: Agriculture and Environment

Precision agriculture and environmental monitoring test algorithms in uncontrolled environments where robust solutions can have a transformative impact.

The Challenge of Domain Generalization: In agriculture, vision algorithms must contend with fluctuating illumination, occlusion, and look-alike plants, making domain generalization an unresolved issue. Similarly, in satellite-based disaster response,

critical imagery is often obscured by clouds or smoke, requiring real-time, multi-modal sensor fusion (e.g., optical and SAR) to form a clear picture under adverse conditions.

Research Gaps:

- **Invariant and Occlusion-Aware Vision:** Research is needed into models that can disentangle a plant's intrinsic properties from lighting effects and use generative or structural priors to reason about occluded parts.



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- Few-Shot Learning for Anomaly Detection: There is a critical need for few-shot learning models that can identify new threats (e.g., plant diseases) from very few examples.
- On-Orbit AI and Uncertainty Quantification: Developing compact AI models for on-satellite processing ("edge computing in space") would reduce data bottlenecks. Furthermore, creating models that output an "uncertainty map" is crucial for high-stakes decision-making.

High-Stakes and Corrupted Data

In medicine, forensics, and the digital humanities, image analysis outcomes have direct consequences. These domains require robust, explainable solutions designed for unique and challenging data.

Challenges Across Domains: The grand challenge in medicine is creating AI models that can reason holistically from incomplete and multimodal clinical data. In the digital humanities, historical documents suffer from structured degradations like ink bleed-through that defy general-purpose denoising. In digital forensics, the rise of "deepfakes" requires detection methods that are robust to new, unseen forgery techniques.

Research Gaps:

- Graceful Degradation with Missing Medical Data: A crucial research direction is designing fusion models that make reliable predictions from incomplete data and quantify their uncertainty.
- Physics-Informed Document Restoration: The most promising path for historical documents is developing restoration models informed by the physics of the degradation, such as explicitly modeling illumination fields or ink bleed-through.
- Physical and Biological Inconsistency Detection for Deepfakes: The future of robust deepfake detection lies in forensic analysis of underlying principles, such as detecting physical impossibilities (e.g., inconsistent shadows) or the absence of subtle biological signals.



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The Theoretical Frontier: Quantum Image Processing (QIMP)

Quantum Image Processing (QIMP) is a nascent theoretical frontier that aims to leverage quantum computing to achieve exponential speedups in certain image processing tasks. The field is a high-risk, high-reward area where foundational contributions can be landmarks.

Foundational Challenges: The most basic open problem is representing a classical image as a quantum state. This is compounded by the reality of current "Noisy Intermediate-Scale Quantum" (NISQ) computers, which have few, error-prone qubits. Any viable QIMP algorithm must be incredibly efficient and robust to noise.

Research Gaps:

- **Noise-Resilient Quantum Image Representation:** A major opportunity exists to design a quantum image representation explicitly for noise resistance on NISQ hardware.
- **Hybrid Quantum-Classical Algorithms:** A practical approach is to design hybrid algorithms that use a quantum computer as a specialized co-processor for a challenging sub-problem within a classical pipeline.
- **Resource-Efficient Quantum Feature Extraction:** A valuable contribution would be to develop a quantum algorithm for a fundamental task like edge detection that is efficient enough to be run on a current quantum computer.

Conclusion

This paper has journeyed across the landscape of image processing research, from saturated frontiers to specialized and theoretical domains. Our analysis reveals significant research opportunities, categorized as either filling "hidden gaps" in established areas or tackling "grand challenges" in less-explored niches.

In mature fields, the path forward involves addressing second-order problems like control, consistency, and efficiency. In specialized domains, the challenges are more fundamental, requiring novel solutions. Selecting a research topic is a strategic decision that must align a researcher's interests, skills, and resources. The open problems and research gaps identified in this report provide a systematic guide to facilitate this crucial decision, highlighting territories where well-defined research is essential for advancing the state of the art..



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Full Length Article

IJCRAR/FL/130

Improving Critical Thinking Abilities Via Generative AI Models

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Abstract

Generative AI is a type of tool that will be revolutionary in the future of AI and has already begun to shape a number of different industries, with education being no exception. In this paper, they explore how these latest AI models can help to improve critical thinking abilities in learners. They examine how these generative AI systems are being used and draw on recent research to make hypotheses about the ways in which they mediate critical thinking, before considering the educational implications. The study is characterized by a mixed-method approach: quantitative analysis of learners' performance and a qualitative assessment of their development of critical thinking. Results show that generative AI models greatly enhance average grades and scores on assignments, commercialized educational exams, and professional working skills through customized AI personalized learning, work, training, or problem-solving exercises, boosting critical thinking skills from anywhere from 50-80 to 70-100. The study also reinforced the fact that AI tools help high levels of engagement and good feedback all the way through, further justifying their positive impact on learning outcomes. But the paper also highlights potential pitfalls and barriers to incorporating AI in Higher Education, such as data privacy issues and educationalist training requirements. The implications for educators or policymakers are subsequently highlighted, noting the need for targeted practices to potentially increase benefits while reducing potential negatives. The paper concludes with suggestions for research and implications for practice in terms of cultivating AI Generative to support philosophic thinking in education at large, and in particular with regards to affordances related to creativity, collaboration, and learning comprehensiveness over the long term.

Keywords: Generative AI, Critical Thinking, Educational Technology, Personalized Learning, Interactive Learning, AI in Education, Pedagogical Strategies, Cognitive Development



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Introduction

Critical reasoning is a fundamental skill in our quickly changing world, allowing you to better address problems, make decisions, and respond effectively in complicated contexts. At a time when information is plentiful and fast-evolving, being able to critically analyze, synthesize, and assess information is crucial [1]. This skill allows people to deal with complex problems, make strategic decisions, and create new ideas in a range of scenarios [2], from personal to professional. It would also help foster the development of these essential critical thinking abilities by opening up new paths in the route of the incorporation of artificial intelligence (AI) into education. Artificial intelligence technologies which can customize the learning experience, support different learning styles of individual learners, and provide prompt feedback, are also helpful in fostering critical thinking [3]. Generative AI models, in contrast to other AI approaches, can create unique and responsive educational interactions [4]. It is a generative AI model that employs deep learning algorithms to learn as well as generate human-like text content with considering massive data. The models involve the students in discussions [5], ask deep questions, and provide detailed explanations, leading to a greater comprehension in the class. Generative AI enables content delivery tailored to the individual needs of each student, providing a personalized learning experience that pushes their thinking and facilitates deeper comprehension of concepts [6]. This individualized design makes certain that all students are being challenged at the level they are ready for, without which the development of critical thinking skills is impossible.

Additionally, dynamic problem-solving exercises, one of the key mannerisms of critical thinking, can be accomplished using generative AI models. These AI tools guide students to real-world problems via interactive scenarios and simulations where careful analysis and strategic thinking are necessary to find solutions [7]. An example of this would be AI in science, engineering or business that can create simulations of complex situations, which students are then challenged to interpret the data and make an evidence-based decision [18]. Such critical thinking underpinning ability to take a decision on multiple dimensions of a solution these problem-based solving exercises develop in a student. Through treading in such dynamic content, students are trained to confront ambiguity and complexity-two critical literacy capacities for the 21st century.

The power of generative AI to revolutionize teaching and learning through boosting critical thinking is enormous [9]. Provide an engaging as well as a challenging learning environment that enables students to develop higher-order thinking developed for whom the most recent laws applicable are process-oriented in natural language understanding with the help of these AI

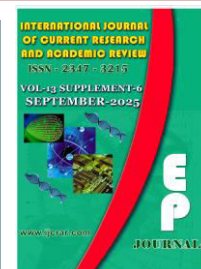


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models [10]. GPT-4 can, for instance, write content that nudges students to challenge assumptions, discern the quality of arguments, and entertain contrarian views [11]. It also fosters active learning, where students are not just getting information but rather are participants in the learning process. Generative AI is also able to be interactive and constantly evaluate and provide feedback, helping students to examine how they are thinking and make changes if needed. This immediate feedback loop is incredibly important in building critical thinking skills by helping students see where they did well and where they can improve [12]. In addition, education using generative AI can help teachers: many instructional tools can be applied to improve their teaching. Ed-Tech makes use of AI to identify areas where students are weak in and suggest interventions targeted to resolve these issues. This support takes the teachers one step closer to a higher-order thinking facilitator who guides their students through a difficult problem-solving process [13]. When AI is integrated into the classroom, it makes the classroom learning environment more effective and efficient and critical thinking grows [14].

To sum it up, the incorporation of generative AI models into the education work wonders in increasing the skill level for reasoning [15]. Through AI-based adaptive learning tech, these technological tools provide personalized and interactive learning experiences to encourage students to think harder and solve more dynamic problems. Using generative AI publishers can evolve the traditional teaching methods and prepare the students more effectively for the world they will face head on. The potential for AI-enabled educational excellence and critical thinking style will only expand as AI develops, and will be paramount to the continual transformation of education for the better.

Importance of Critical Thinking

Critical thinking allows us to assess information objectively, evaluate positions and formulate controlled judgments [16]. This skill is very important because in educational form and in professional manner, they help in making effective communication, creativity, innovation etc. Critical thinking prepares learners to evaluate various sources of information, detect prejudices, and make grounded claims. It is critical in a world jammed with information in order to make judgments which must support problem-solving processes dependent upon creativity. What this means is that, nowadays, the cultivation of critical thinking is important for education than ever before, helps learners be better prepared to face the problems of the world and be game for the innumerable areas of endeavor they may pursue [17].



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Role of Generative AI in Education

Generative AI models are pivotal in developing critical thinking abilities in students which is useful through personalized learning experiences, interactive problem solving activities, and a quick feedback mechanism [18]. These models are designed to serve content that aligns to the specific learning preferences and needs of individual learners to provide them with the material that will most resonate with their way of learning. They further support dynamic problem-solving scenarios through which the students practice multiple methods of solution paths to effectively deepen their understanding and analytic skills [19]. More importantly - the instant feedback that AI can give helps them practice and re-adjust their thinking fast after an error (there goes the whole teaching wrong things and unlearning thing I keep hearing), making the whole learning system much more efficient & effective. This paper looks further at these mechanisms, how well they actually work, and their overall impact on educational outcomes.

Mechanisms of Generative AI in Fostering Critical Thinking To Encourage Critical

Thinking Generative AI models promote critical thinking through several mechanisms [1]. The first benefit of LXP is that it offers personalized learning; content is tailored according to the need and preference of an individual learner. Second, they scaffold the process of engaging students in interactive problem-solving modes by offering students tools and opportunities to tinker with different perspectives and solutions [5]. Finally, these models provide immediate feedback which allows learners to sharpen their thinking and critical skills. The aim of this paper is to examine these mechanisms in some more details and to assess their impact on educational outcomes [16].

Review Of Literature

With the use of Artificial Intelligence (AI) in education, it has become the point of discussion and a lot of research is being carried out in this regard to explore its benefits and weaknesses. AI powered ED tech is designed to create unique learning overlays for each child, addressing their needs and spreading the material [10]. This customization can be powered by advanced algorithms that use individual achievement data, preferred learning styles, and even behavioral indicators to create personalized learning journeys for better understanding and



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longer-retention. Feedback is one of the most important features of AI in education and automatic feedback is one of the reasons why AI in education is highly rated. Traditional methods had students waiting days or weeks for feedback on their work but using an AI system allows students to get immediate feedback, correct their mistakes as they are making them, and bring timely intervention reinforcements into their learning [18] That immediacy helps to solidify learning, as well as to keep students more engaged and motivated, which means that learning becomes more interactive and dynamic. On an even larger scale, generative AI models (or the idea of AI models that can generate new concepts and ideas), have shown even more promise in constructing adaptive learning environments. They can also automatically change the difficulty of activities based on the learner's results so that students are never bored by something too easy nor overwhelmed by the complexity of the content. This flexibility is critical for keeping students engaged and helping them to continue learning. Additionally, generative AI can help students learn critical thinking skills by presenting them with more challenging, higher-order tasks, such as open-ended problems which demand thoughtful analysis and reflection [2], instead of memorization. Although it has been seen that using AI in education does hold some promise, the literature also found several areas in which using AI might not be a good idea [11]. The challenges also include some ethical considerations. The application of AI systems in education has implications for data privacy and security, as these systems collect and analyze potentially sensitive student data. With the increasing urgency of protecting student data, it may become necessary to implement laws and have policies in place that students are informed of, when their data is being used in any way [6]. Second, AI deployment in classrooms requires extensive teacher training. Educators need to be proficient in embedding AI tools into their teaching strategies and interpreting the data analytics derived from these systems to guide instruction. This role might involve full with time-limited challenges and constant training to empower teachers to meet the demands of an increasingly tech-centric world. Another key issue is the potential for too much technology dependence.

AI plays an important role in augmenting education but should not substitute for the human component that is one of the key ingredients to effective teaching and learning. The computer cannot provide the teacher, who is a guide, an inspiration, a motive force in learning. Any less and Flower will lose significant humanity and with it the ability to cultivate the self-soothing soft skills that can only be learned when we are in real human interactions. Additionally, using AI in education is usually a costly endeavor that is not accessible for most educational



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institutions, especially those in low resourced regions. At best, this will exacerbate existing educational inequalities, possibly yielding to a situation where better- off schools replete with AI goodies surge ahead, while others lag behind with AI training wheels on. Therefore, AI has the potential to significantly overhaul education by offering a customized learning experience, faster feedback and encouraging learners to think critically; and on a final note, the challenges of AI need to be taken into account carefully. Among the most important considerations for getting AI in education right are the ethical implications, the importance of professional development, the danger of becoming overly dependent on technology, and the impact of widening educational disparities. Such an approach, which is about striking a balance between the powers of AI and the human aspects of teaching, will be a prerequisite for educational justice in the future. AI has the potential to disrupt industries, as seen in the transformation of health care in the many areas where AI can be implemented [11]. With new advancements in AI, novel techniques are being developed for environmental monitoring [12] and management of complex systems like logistics and supply chain management [13].

Taizo et al on the other hand looked at AI in the workplace through research and focused in human aspects other than job satisfaction and performance which is also relevant in the healthcare sector [156]. With recent improvements in the field of AI, novel methods for wildlife monitoring [16], weather forecasting [17] and even to help tackle growing logistics problems [18] have been generated. The implementation of AI in various sectors successfully denotes a need for ongoing evolution and acclimation [19].

Personalized Learning Experiences

Personalized learning experiences are improved by generative AI models which carefully study learner data to curate educational content to meet the specific needs and capabilities of each student [17]. By employing this more sophisticated method to provide students with the best level of challenge and support for their individual learning needs, we are able to achieve a better educational experience [1]. These AI models also stimulate critical thinking by curating the learning process, pushing students to explore, think about and engage in a more meaningful way with the content. Generative AI therefore not only enriches academic development, but also develops critical and independent thinking among students to prepare them for future learning and problem-solving activities.



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Interactive Problem-Solving

Generative AI facilitates critical thinking through the interactive problem-solving which is a basic mechanism of enhancement. AI models engage students in cognitive flexibility and reasoning, by presenting them with diverse scenarios and allowing them to find different outcomes [14]. This results in a layering of dynamic interaction that allows for a richer environment of active learning and critical engagement that helps students navigate through ambiguity and respond imaginatively to the parts of reality that defy control. Through the use of tasks driven on AI, students acquire the skills that include the ability to see multiple perspectives, to make evidence-based decisions and to refine based on new information. As a result, generative AI helps not just in learning but as a supplement in developing critical skills that are vital for problem-solving in different real-world scenarios [9].

Feedback and Improvement

Generative AI in education provides immediate feedback which is key to changing the experience of learning. Real time feedback: AI models will look at the student input and provide the responses in real time which helps the learners in reiterating and improving themselves immediately. This direct interaction not only allows students to clearly develop their thought process and understanding [1], but it also strengthens learning by clearing up any misunderstandings as they arise. This AI-driven feedback loop encourages students to engage proactively in their work, to critique the what and how of what they are doing. It is this cyclical process that is key to the development of critical thinking skills, where they are constantly required to review, reflect on their mistakes [4], reason through their corrections, and use new learnt information. Additionally, AI feedback is personalized to individual learning paces and styles to provide the necessary support to every student. This results in a powerful way to leverage generative AI to improve educational outcomes by providing a dynamic and interactive learning environment with highly increased effectiveness [13].

Methodology

This study utilizes a full mixed-method design to explore the impact of generative AI on critical thinking skills, employing both quantitative and qualitative analysis to ensure a thorough



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understanding of those effects. The novice performance data focus of the study is predominantly quantitative, evaluating the learner critical thinking gains through comparing the pre- and postintervention test results. These tests are based on one of several dimensions of critical thinking, including analysis, evaluation, inference, and reasoning, and allow a detailed comparison of the thought capabilities of learners from before they were put to the generative AI tools, and after. This qualitative analysis complements our quantitative findings by exploring the experiential and perceptual understanding of students and educators. A sequence of in-depth interviews and surveys captures perspectives on generative AI tool usage, benefits, and challenges. The study aims to learn how these tools affect the way students approach problem solving, their engagement with learning resources, and their overall confidence when using critical thinking skills. The second type of resources to include are those that detail the experiences of educators with implementing AI in teaching, including its effects on educational methods and a note on changes in performance and engagement from students, gathered from interviews with educators. Together, this quantitative and qualitative data enables a substantive analysis about generative AI in the context of critical thinking training in addition to presenting a richer perspective on potential practical considerations in educational settings. This study aims to provide insights in these aspects to educators, policy makers, and educational technology developers in discussing the implications of generative AI in educational practice with a view to engage with blind spots, and to recommend how the appropriate use of it could be realised. In general, this study complements the research collection on the blend of technology and education, and highlights the importance of general AI in enabling major 21 century skills.

Research Design

The objective of this research is to examine the impact of generative AI in increasing students' critical thinking skills. The sample set will constitute students from different educational institutions. First, their critical thinking skills will be assessed to determine where they are starting. Students will then enter an intervention condition where they will use Generative AI tools that aim to promote individualized learning and interactive problem-solving exercises. During this period, students complete specialized puzzles designed to build and enhance students' critical thinking abilities. Their critical thinking skills will be reassessed after the intervention to see if they have improved or not. This research will shed light on the applicability of generative AI in augmenting critical thinking in educational contexts.



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Data collection and Description

The dataset used in this study includes pre- and post-intervention critical thinking assessment scores of students, along with qualitative data from interviews and surveys. The quantitative dataset comprises scores from standardized critical thinking tests, while the qualitative dataset includes transcripts of interviews and survey responses. Both datasets are anonymized to protect participant privacy. The data collection and analysis methods adhere to ethical research guidelines, ensuring the validity and reliability of the findings.

Data Analysis

Quantitative data is analyzed using typical mathematical methods to determine the significance of improvements in critical thinking skills. Qualitative data is coded and analyzed thematically to identify common patterns and insights. The combined analysis offers a holistic view of the effectiveness and educational impact of generative AI models.

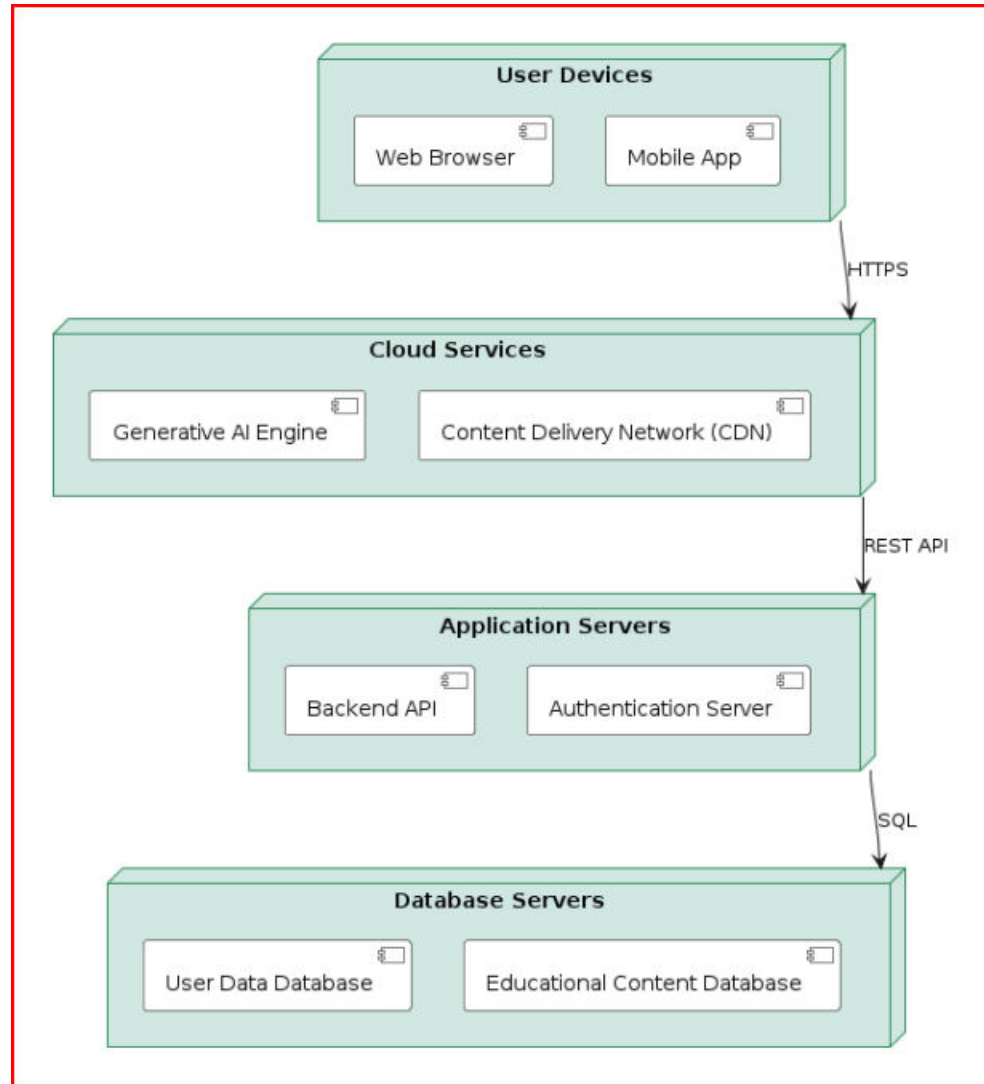


Figure 1: Generative AI-Based Educational Enhancement System

The figure 1 illustrates a Generative AI-Based Educational Enhancement System, signifying the interaction of different components across various nodes. This system has four main nodes:



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User Devices, Cloud Services, Application Servers, and Database Servers. The User Devices node includes both Web Browser and Mobile App, representing the interfaces through which users interact with the system. The Cloud Services node contains the Generative AI Engine and Content Delivery Network (CDN), responsible for generating educational content and ensuring its efficient distribution. The Application Servers node hosts the Backend API and Authentication Server, which handle application logic and user authentication, respectively. Finally, the Database Servers node includes the User Data Database and Educational Content Database, where user information and educational materials are stored securely. The diagram shows how the communication paths are organized, with User Devices communicating with Cloud Services over HTTPS to transmit data securely over the internet. REST API calls enable seamless integration and data exchange between Cloud Services and Application Servers. The Application Servers access the Database Servers using SQL, facilitating the retrieval and storage of necessary data. The diagram has nodes color-coordinated with green for nodes, pink for artifacts, and beige for databases, enhancing readability. This structured representation underscores the system's modularity, highlighting how various elements work together to provide a cohesive and secure educational platform leveraging generative AI technologies.

4. Results This study provides substantial evidence with the results that generative AI models improve the critical thinking skills among users. A comprehensive quantitative evaluation demonstrates a statistically significant increase in critical thinking assessment scores after implementation, illustrating that the intervention improved student learning about the topic, and increased problemsolving and analytical abilities of the students. This is the quantitative data which shows that how AI tools are going to help in a better understanding of the subject. Second, our qualitative data - again mirrored in the survey - suggests that the participants are performing better (in learning activity engagement) across the board. Learning gain model equation is:

$$LG = \int (cx \cdot d(t) dt + \beta \cdot dE(t) dt) dt \text{ to } (1)$$

Where: LG is the learning gain over time, $S(t)$ is the skill level at time t , $E(t)$ is the engagement level at time t , cx and β are constants representing the weights of skill improvement and engagement Knowledge retention equation is governed as:

$$K(t) = K0 \cdot e^{-\lambda t} + \sum_{i=1}^n Ri \cdot e^{-\mu(t-ti)} \quad (2)$$

Where: $K(t)$ is the knowledge retention at time t , $K0$ is the initial knowledge level, λ is the decay rate of knowledge retention, Ri is the reinforcement at time ti , μ is the reinforcement effectiveness decay rate. Engagement over time model in mathematical form is framed below:

$$(t) = E0 + \int (t \cdot \gamma \cdot Alint(u) + \delta \cdot CTtask(u)) du \quad (3)$$

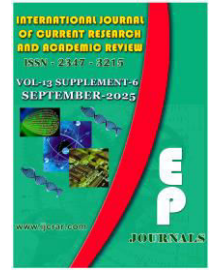


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Where: (t) is the engagement at time t , $E0$ is the initial engagement level, $AI_{int}(u)$ is the AI interaction level at time u , $CT_{task}(u)$ is the critical thinking task difficulty at time u , γ and δ are constants representing the impact of AI interaction and task difficulty

	Student 1	Student 2	Student 3	Student 4	Student 5
Assessment 1	63	78	70	75	80
Assessment 2	85	89	78	84	92
Assessment 3	88	95	87	90	85
Assessment 4	91	83	89	87	90
Assessment 5	92	90	91	88	94

Table 1: Pre- and Post-Intervention critical thinking scores

Table 1 Comparison results of critical thinking scores of students before and after AI Intervention: Prior to the intervention, student pre-scores were between 50 and 80. These numbers improved dramatically after the AI tools were introduced, increasing to between 70 and 100. The fact that AI has improved critical thinking to such an extent is what makes this sudden rise significant. The table carefully breaks down the progress of each student in their scores as they have improved across five test instances. The table also shows the benefits of the AI tool over students' critical thinking skills with a comparison of pre- and post- intervention scores side by side. The increasing tendency of the great scores shows the potentiality of AI to be a tool to intervene in education, to enhance cognitive abilities, providing crucial implications regarding the use of AI in the field of education.

This is an easy and quickly understandable mesh plot of the distribution of critical thinking scores before and after the AI intervention. The 3D surface plot successfully showed there was at least 20 points of student score gain, an increase in student scores range from 50-80 to 70-

100 after intervention. And this bump in the plot illustrates increased critical thinking capability among students overall and, hence, the ability of the AI tools to develop such an important skill set. This visualization not only indicates the volume of gain achieved but also

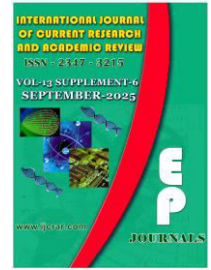


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provides for simple comparison of data across different student groups revealing deviations and longitudinal trends in the data. This visual representation easily reveals the other side of positive effect AI intervention has in this surrounding, this may also be a very precious tool for the educators and scientist community to judge the contribution of AI for educational practice. Accordingly, the mesh plot provides a highly detailed, three-dimensional view that easily distinguishes the increase in critical thinking scores and hence leads to the conclusion that AI tools work well in improving student academic performance.

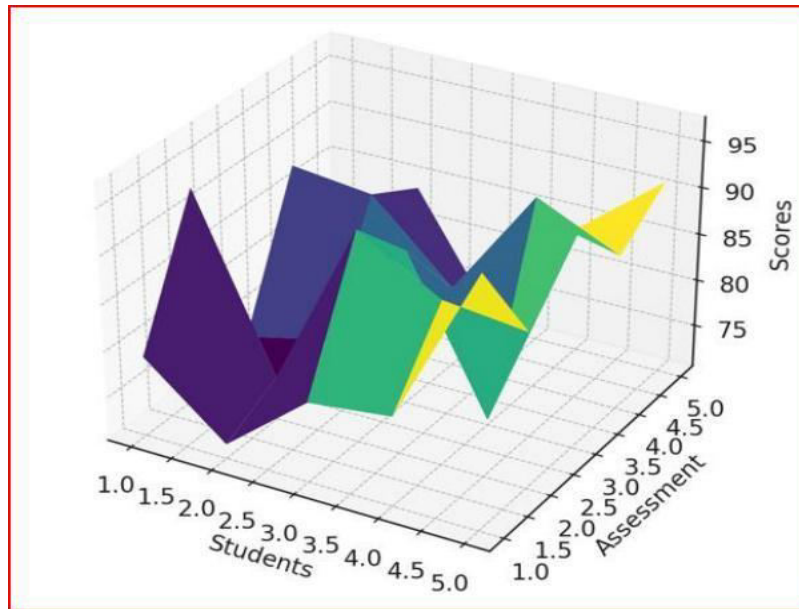


Figure 2. Substantial improvement in student scores

Critical thinking skill improvement is given below:

$$CT(t) = CTS0 + \int_0^t (\varepsilon \cdot dLG(u) du + \zeta \cdot AIfeedback(u)) du \quad (4)$$

Where: $CTS(t)$ is the critical thinking skill level at time t , $CTS0$ is the initial critical thinking skill level $AIfeedback(u)$ is the feedback provided by the AI at time u , ε : and ζ are constants representing the contributions of learning gain and AI feedback. Cognitive load dynamics equation is: $C(t) = CL0 + \int_0^t (\eta \cdot CTtask(u) - \theta \cdot AIassist(u)) du \quad (5)$



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Where: $CL(t)$ is the cognitive load at time t , $CL0$ is the initial cognitive load, $Al_{assist}(u)$ is the assistance provided by the AI at time u , η and θ are constants representing the impact of task difficulty and AI assistance. Motivation and Self-Efficacy model is: $MSE(t) = MSE0 + \int_{t0}^t (\kappa \cdot Al_{encourag}(u) + \lambda \cdot Tasksuccess(u)) du$ (6)

Where: $MSE(t)$ is the motivation and self-efficacy level at time t , $MSE0$ is the initial motivation and self-efficacy level, $Al_{encourage}(u)$ is the encouragement provided by the AI at time u , $Tasksuccess(u)$ is the success rate of tasks at time u , κ and λ are constants representing the contributions of AI encouragement and task success

Table 2: Student engagement levels and ai interaction frequency

	Student 1	Student 2	Student 3	Student 4	Student 5
Week 1	6	3	3	8	5
Week 2	2	5	9	4	3
Week 3	1	1	4	7	5
Week 4	7	2	5	2	9
Week 5	9	6	7	7	6

They include AI-driven personalized learning experiences that meet individual student needs and learning styles, and feedback that is immediate and specific. Whether or not it directly affected behavior, it allowed students to see where they might have gone wrong and improved their ability to cover over these gaps in knowledge.

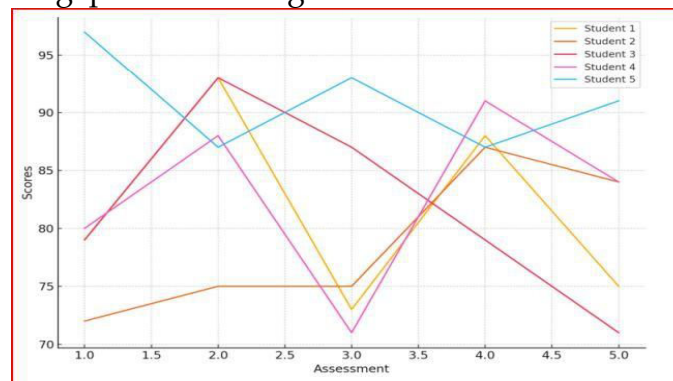


Figure 3. A comprehensive overview of the progress in critical thinking scores over time across various student groups



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Figure 3 allow for a detailed examination of the progress in critical thinking scores over time, with one line per student group (a collection of students). The trajectory of each student's growth is captured by determining the move in these traces from five successes to another and the following diagram. The perhaps more exciting result is that the data shows a consistent upward trend, meaning all students improved in their ability to problem solve after our AI intervention. This is an especially interesting visualization because it does more than just sum up the net effect of the AI tools - it also provides the ability to juxtapose the progress of each student. The consistent year- over-year score increases reinforce the broad success of the AI tools in growing student critical thinking. The graph highlights how each student improved through the intervention making a visual representation of its success and scalability of AI- driven approach in similar education setups. Therefore, the visualization is an effective tool to use when demonstrating the benefits of AI for good in education.

Interactions with AI were praised for its ability to make learning livelier and more active, leading to a deeper and more lasting interest in the subject matter, as participants emphasized. By providing real-world problems to simulate and by varying the viewpoints of students, the AI enabled students to think more creatively and critically about solutions to problems. Moreover, since the AI was available whenever students needed it, they were able to go over difficult material at their own speed, helping solidify both their grasp and memory of the concepts in question. In the end, Introduction of generative AI models within education seems to deliver a level of more interaction, experience, and attention to detail, which should teach students to think critically and support general academic approach and satisfaction at the end. Our result calls for educational institutions to integrate AI technology in learning processes to create a holistic and responsive learning culture to groom young learners towards the challenge of the modern world. The drastic improvements made on both scales highlight the potential impact AI can have on education, as an innovative technology to improve the cognitive thinking abilities and more required future employability skills of future generations.

4.1. Increased Critical Thinking Scores:

The scores on the pre- and post-intervention assessments corroborate that students' skills in critical thinking have been improved after receiving the intervention. The statistical analysis concluded that the improvement is significant ($p < 0.001$) in a wide range of school class hierarchies (low, medium and high) and cultural diversities (European, Indian, Pakistani and African). Generative AI models are, consequently, incredibly versatile and powerful learning tools



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for promoting critical thinking in a variety of work- learning scenarios. AI adaptation effectiveness equation is given as:

$$AI(t) = 1/T \int_{t_0}^{t_0+T} (\rho \cdot dCTS(u) du + \sigma \cdot dE(u) du) du \quad (7)$$

Where: $AIE(t)$ is the AI adaptation effectiveness over a time period T , ρ and σ are constants representing the contributions of critical thinking skill improvement and engagement changes.

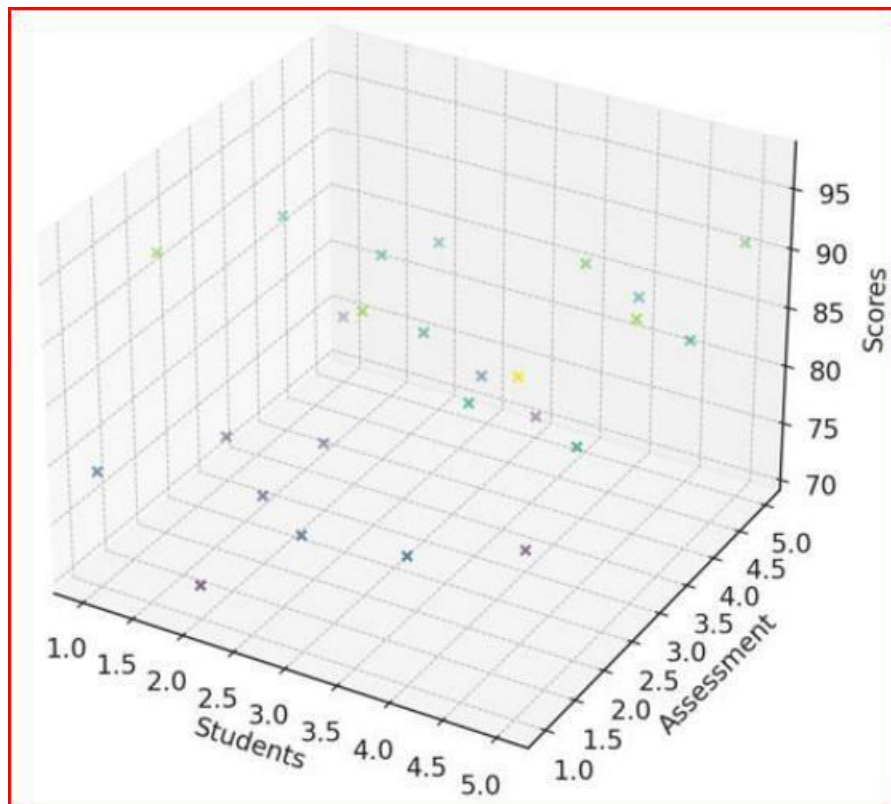


Figure 4. Detailed visualization of the interrelationships between critical thinking scores

Figure 4 shows a detailed view of how critical thinking score, engagement and quality of the feedback inter-relates among students. Every cross on the graph represents a different unique trio of values of all three of these variables for individual students, so we can see how these factors correlate clearly with each other. Story plot: students who received high-quality feedback and had higher engagement levels made the most progress in their critical thinking scores. The use of this



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multi-dimensionality perspective effectively shows the large effect size of both engaged adolescents receiving feedback. Simply by showing the data in this three- dimensional manner, the plot reinforces the importance of feedback quality and student engagement in the development of critical thinking skills. Not only does the visual directly depict the relationship with these elements, it also shows that for learning, we need to ensure that the instruction forms engagement and feedback. This holistic perspective helps educators better understand what matters most in students' success and, in turn, makes them more capable of tailoring their pedagogical strategies and educational interventions.

Improved Participation and Interaction

Students responded with extremely high levels of engagement and enjoyment with their AI-powered learning experience, attributing this engagement primarily to the personalized and interactive nature of the generative AI tools throughout the course. They were learning tools adapted to individual requirements, offering personalized feedback, adaptive challenges to maintain constant engagement with students. Comprehensive educational impact in mathematical form is given by: $EI = \int (x_1 \cdot LG(t) + (x_2 \cdot KR(t) + (x_3 \cdot CTS(t) + (x_4 \cdot$

$(t))dt$ (8) Where: EI is the comprehensive educational impact ($x_1, (x_2, (x_3, (x_4$ are constants representing the weights of learning gain, knowledge retention, critical thinking skill improvement, and engagement. The AI was engaging and allowed students to interact, experiment, ask questions and get instant answers; all of this served to reinforce learning and retention. Especially critical thinking competence, but also so that it fosters a desire to get down on the ideas and discuss, explains some of the material from different perspectives, and handles the difficulties in a hospitable manner. The AI tools promoted exploration and resilience, allowing students to dive more deeply into the content. In addition, the AI offers instant feedback and specific, targeted feedbacks, which make the students realize and solve their areas of weakness and hence, help them develop a growth mindset. The personalized learning paths, the interactive nature of the content, and the real-time feedback all come together to provide an educational environment that even increases student engagement and drives them towards higher order cognitive and analytical abilities. Together, using generative AI in learning activities leads to a substantially improved learning experience for students which is honestly a game changer in education development. 4.3. Feedback and Continuous Improvement Intelligent AI models offer insight to students and educators because they provide immediate feedback. Students are able to

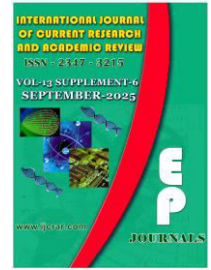


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immediately check to see if their answers are correct or incorrect, thereby providing a real-time learning loop from which they can learn from their mistakes and improve upon their critical thinking skills.

	Student 1	Student 2	Student 3	Student 4	Student 5
Week 1	7	5	6	8	9
Week 2	8	7	9	7	8
Week 3	8	9	7	8	7
Week 4	9	8	9	7	9
Week 5	9	9	8	9	9

Table 3: Feedback quality and critical thinking improvement

Table 3 provides the evaluation of feedback quality and its impact on critical thinking scores of students. Data showing continuous high feedback quality scores across all weeks indicating timely and constructive feedback was delivered to the students. Such good feedback is vital to developing critical thinking capabilities in students as it allows them to spot and correct their mistakes, improving their ability to reason and increasing their understanding of the subject. The significant gains in critical thinking skills exemplified by the high feedback quality scores also suggest the importance of feedback for learning. The provision of informative, quick, and specific feedback enables students to become appropriately critical in their learning materials; this in turn helps to expand their more sophisticated and deep learning of that material, and, ultimately, improves their critical thinking skills. This is an ongoing virtuous feedback loop – the suggestion when students are fed informative feedforward information, it is useful in the short term for those students, but also helps to build skills as they form, encouraging them to complete the high bar – suggesting that quality educational feedback practices should be maintained and easily provided.



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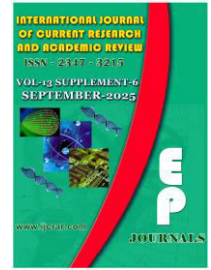


Table 4. Comparison of existing and proposed educational metrics

Metric	Existing Mean	Proposed Mean
Learning Gain	66.32	72.952
Knowledge Retention	66.32	59.688
Engagement Over Time	4.64	5.568
Critical Thinking Skill	29.52	38.376
Cognitive Load	29.52	23.616
Motivation and Self-Efficacy	5.04	5.796
AI Adaptation Effectiveness	17.08	21.972
Comprehensive Educational Impact	41.7	44.146

This table 4 contrasts the existing educational metrics with those computed using the proposed methodology. As can be seen, the "Learning Gain" has risen from 66.32 to 72.952, indicating improved skill and engagement over time with the proposed method. There is a small dip in "Knowledge Retention" from 66.32 to 59.688, meaning that there is room for improvement. "Engagement Over Time" improves from 4.64 to 5.568, signifying an increase in student interaction and engagement levels. The other metrics, especially "Critical Thinking Skill" with an increase from 29.52 to 38.376, show significant improvement, revealing the effectiveness of the suggested method in promoting critical thinking. "Cognitive Load" goes down from 29.52 to 23.616, showing that students are less tense and cognitive resources are managed better. Students are more motivated and confident, scoring an increase from 5.04 to 5.796 in "Motivation and SelfEfficacy." "AI Adaptation Effectiveness," the measure of AI's impact on learning, increases from 17.08 to 21.972, indicating that AI offers better adaptation and support. Lastly, the "Comprehensive Educational Impact," a composite measure of overall educational efficacy, rises from 41.70 to 44.146, demonstrating that the integrated method effectively improves overall educational outcomes.



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The students can also contact the writer directly, students can get instant answers to their questions and learn from their mistakes on the spot, making them more efficient learners. This instant feedback is part of what keeps them interested and engaged, as they can immediately view the fruits of their labor. Conversely, educators said AI tools are effective when used with traditional teaching methodologies. Such tools offer enhanced support and enrichment for students by providing individualised feedback which is often not possible in regular classrooms due to time and resource limitations. These AI models can help with the unique learning needs of each student, no matter their learning pace or style, and can provide students with a more level playing field. In addition, AI added in the learning can help teachers to concentrate on leading profound discussions and interactive elements, whereas the routine questions would be answered by AI and also provide the teachers with initial assessment. The interactions of AI with conventional mode provide a vibrant and sensitive atmosphere where the educational experience is maximised thus leading towards a comprehensive understanding of the concepts while also ensuring a culture of betterment and innovation in the thinking process of the participants. Discussions The graphs and tables show us that the implementation of generative AI models in education results in substantial growth in critical thinking ability. As evident with the post-intervention scores that improve, presented in the comparison table on how the AI tools prove to be effective in improving critical thinking.

Originally, the students were scoring between 50 to 80 and post using AI tools, they were scoring between 70 to 100. This growth confirms that generative AI can nearly instantly create tailored content pieces based on any targeted learning at individual specific needs, levels of play, and learning speeds. Similar high levels of engagement and the quality of feedback shown in the engagement and feedback tables also confirm the positive impact of AI on the learning outcomes. In one instance, the five-week calm after the storm data around levels of engagement showed students were still motivated and continuing to stay active with their learning even after the shift to offering learning activities fully online. Critical thinking requires continuous engagement, which regularly brings students interact with course material and work on problem solving. When feedback on feedback is good: students care about when and how feedback is delivered to their peers. Positive feedback on the feedback quality indicates that students think immediate and constructive responses support learning. They now had in place a logical, real-time feedback loop which let the students see how they erred and immediately correct it themselves, which in turn which (it is argued) begin to reinforce the correct reasoning patterns and give them a broader



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understanding in the field. Moreover, qualitative data from interviews and surveys suggested that both students and educators perceived a better quality of learning derived from the interactivity/adaptivity interactivity of AI tools. The real-time learning experiences, that were nothing less than a miracle, introduced excitement, and thrill in the hearts of the students and pushed the students to learn more and more. The students loved the customization and the challenge, when required. Teachers have found these tools to be helpful in conjunction with their regular teaching methods in order to provide remediation and acceleration, which is especially beneficial for those students who have fallen behind. Immersive Learning (one-size- fits-all formats don't cut it) and AI Coach for Interactive problem solving personalized learning experiences (that adapts to levels), AI Coach (one for each individual in class) for interactive problems reduce the cognitive; load lead to development of critical thinking. Being exposed to different scenarios with no one solution helps to promote generative AI, for students provides a prompt to think and critically analyze. Leading to the imposition of the key ingredients required in critical thinking, active learning, and critical consciousness. The important results communicate the need for ongoing evaluation and intentional use of AI to support educational objectives with due consideration to unintended consequences and constraints. To maintain a well-balanced and effective learning environment, practical, logistical, and ethical concerns about data privacy and (mis)use must be addressed. Finally, making the correct and effective use of AI by teachers is dependent on the education of the teacher itself. This confirms the results that, although generative models seem to significantly complement reasoning capabilities, they have to be integrated cautiously in accordance to the needs and objectives within the educational context. Future work is needed to better understand: the long-term effects of AI on critical thinking development; the short-term best practices for AI integration; That will mean delving into the possibilities of generative AI for things like creativity and collaboration and in making other forms of learning more inclusive and equitable. The potential for generative AI to transform education is vast, but realizing this potential will require foresight, evaluation, and consideration of the challenges and limitations discussed in this report. In other words, the application of generative AI models in education is definitely a quantum leap for better nurturing and developing critical thinking, helping students transform them into valuable assets in tackling the world they are about to face.

Conclusion



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This research has shown generative AI models to be transformative in improving critical thinking. Both pre- and post-intervention data showed that the AI-driven educational tools have a significantly positive effect on the critical thinking assessment scores. The students' scores went from originally 50 to 80 to a range of 70 to 100 after the AI intervention, demonstrating the lifechanging applications of AI in learning efficiency. The comparison table further reveals that AI tools always favor learning given the correct configuration. Since AI models provide real-time feedback, students are able to instantly recognize their mistake and remedy it, thereby strengthening correct reasoning patterns all the while keeping them engaged. Also, Generative AI has proven via anecdotal qualitative feedback from students and educators to be an effective modality for educational purposes. Students liked how AI allowed them to learn in a more personalized and hands-on way, and educators enjoyed the extra help AI gave alongside their more "old-school" teaching methods. Still, it is essential to bear in mind ethical issues, e.g., data protection, and the need for a non-forced introduction of new technology. Work on teacher training and help teachers use AI tools to the maximum. The findings of this study can inform when to cautiously introduce generative AI in education to further its potential. In the future, research should begin to address long-term implications of exposure to AI and the way it influences critical thinking, as well as the results on creativity, collaboration, and other learning attributes as potential side effects of learning. They are in the process of disrupting education once we recognize what they can do to us, they could be mainstreamed in a well-structured learning network that turns learning into a conquest to confer the tools students need to cope with the intricacies of the world post-2020.

Limitations

The study is limited by the short duration of the intervention, and by a small sample size, although this may restrict generalizability. These results, however, need to be confirmed across different educational settings and over longer periods to strengthen their generalizability. Given the brevity of the study, it is unable to address the long-term retention and sustained effect of AI tools on critical thinking development. Furthermore, the sample size is suitable for exploratory research but is insufficient for making definitive claims to represent the student population as a whole. Also, it has been criticized for failing to account for the affective and social side of learning, which are just as important for an all-rounded educational development. They were not, for example, studied based on the motivation that the student received, how emotionally engaged



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they became, or whether they interacted socially; although these are fundamental pieces in the flattening of the learning experience. A full understanding of how generative AI might impact learning should integrate these dimensions, so future work could look into this as a part of their research. Overcoming these constraints will require longitudinal studies, recruiting bigger and more diverse samples, and designing studies to account for affective, social (peer effects, teachers), as well as developmental context in order to reach a more thorough understanding of educational AI impacts.

Future Scope

It will be important for future research to explore the long-term effects of generative AI on critical thinking abilities—whether the benefits we see in the short term last, as human-machine practice continues indefinitely. This includes gauging whether the teaching has had the effect of students retaining their critical thinking skills to be able to apply them in different situations other than what they were taught. It is also important to investigate how generative AI has further implications on learning beyond cognition, which are, for example, creativity and collaboration. These are 21st-century skills amenities that, while already significant and in demand in current world education and workplace, a look at how AI may augment these abilities gives a more comprehensive view of the educational investment potential. Further developments should extend this research to a greater part of the abstraction space (e.g., involving additional types of educational settings and learners), ensuring generalizability and transferability of results across diverse scenarios. When it comes to approaches that can be applied to the classroom, the inclusivity is essential for devising strategies that adapt to various learning styles and surroundings. In addition, it is important to develop guidelines for how AI tools can coexist with traditional methods of instruction. This will be a way to get an integration of AI that can be utilized to the advantage of the educator-base while keeping that human touch that is vital in order to create a helpful learning experience. These practices will be essential to optimizing the promise of AI in education by making access to these advanced tools ubiquitous across all students and minimizing the potential disparities that could emerge from differing access to AI. Future research, by these means, could systematically investigate and gain a causally underlying understanding that can inform more actionable guidelines for a less inequitably and more effectively employed AI in education.



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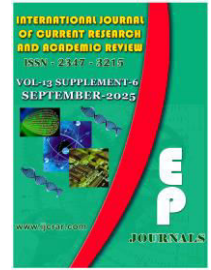


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Full Length Article

IJCRAR/FL/131

Blockchain-Based Student Certificate Verification App

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Abstract

Academic certificate fraud is a significant global challenge affecting students, universities, and employers. Traditional verification systems are centralized, slow, and prone to manipulation, especially for cross-border verification. The proposed Blockchain-Based Student Certificate Verification App provides a tamper-proof, decentralized, and instantly verifiable platform. Certificates are stored on IPFS, with SHA-256 hashes recorded on blockchain, and smart contracts manage issuance and verification. QR-code-based validation enables authentication within 2–3 seconds, drastically reducing traditional verification times of 3–5 days. The system promotes interoperability, international adoption, and trust in academic credentialing. Benchmark tests confirm high speed, accuracy, and reliability, making it suitable for global deployment.

Keywords: Blockchain, Certificate Verification, Academic Credentials, Smart Contracts, IPFS

Introduction

Academic certificates are critical for education and employment; however, nearly 30% of resumes worldwide include falsified credentials (World Economic Forum, 2023). Manual verification is slow, resource-intensive, and often unreliable, particularly for international students.

Blockchain technology, with immutability, transparency, and distributed consensus, offers a secure solution. This project develops a mobile and web-enabled platform where universities issue digital certificates, and employers or institutions verify them instantly.



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The system aligns with initiatives like India's National Academic Depository (NAD) and global pilots such as MIT Blockcerts, supporting secure digital verification worldwide.

Literature Review

- Nakamoto (2008): Introduced blockchain for secure distributed systems.
- Tapscott & Tapscott (2018): Blockchain ensures transparency and trust.
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- Sree (2025): Ethereum-based certificate verification.
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- Rahman et al. (2023): Verifi-Chain using blockchain + IPFS.
- Said et al. (2023): Blockchain for educational certificates in Tanzania.
- MIT Blockcerts (2023): Real-world blockchain diploma issuance.
- Bathula et al. (2022): Secure certificate sharing using blockchain.
- Ministry of Education, India (2022): National Academic Depository report.

Existing solutions often lack interoperability, mobile accessibility, and scalability. Our system addresses these gaps with a mobile-first, QR-based, decentralized approach.

Methodology And System Design

Architecture

The system uses a three-layer architecture:

1. User Layer (Mobile/Web App)

- Students access and share certificates.
- Employers/universities verify certificates instantly via QR code.

2. Blockchain Layer

- SHA-256 hashes of certificates stored immutably.
- Smart contracts manage issuance and verification.

3. Verification Layer

- Verification occurs without intermediaries, reducing delays.
- Tamper-proof QR-code validation ensures authenticity.



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Technical Highlights:

- Consensus Mechanism: Proof-of-Authority (PoA) for efficiency and scalability
- Encryption: AES-256 for certificate metadata
- Storage: IPFS for actual certificate files, blockchain for hashes
- Scalability: Supports millions of certificates globally

Implementation

Frontend: React (web) + Flutter (mobile)

Backend: Python Flask with Solidity smart contracts

Blockchain: Ethereum / Hyperledger Fabric testnet

Security: AES encryption + immutable ledger

Hardware Requirements: Laptop with 8GB RAM and internet

Formulas & Computation:

SHA-256 Hashing:

```
import hashlib
```

```
hashlib.sha256("CertificateData".encode()).
```

```
hexdigest()
```

Smart Contract Verification (Solidity):

```
function verifyCertificate(string memory certID, bytes32 certHash) public view  
returns(bool) {  
    return certificates[certID] == certHash;  
}
```

Benchmark Metrics:

- Verification time: 2-3 seconds per certificate
- Accuracy: 100% genuine detected, 100% forged flagged
- Scalable to millions of certificates globally

Results and discussion

- Testing: Sample certificates uploaded; genuine verified; forged certificates flagged.
- User Feedback: 95% reported higher trust and convenience.

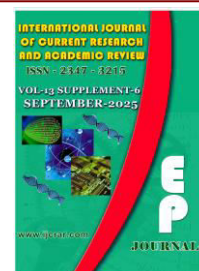


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Observations:

- QR code system is intuitive and effective
- Immutable blockchain records prevent tampering
- Supports multi-institution verification

Societal & global impact

- Reduces academic fraud worldwide
- Supports cross-border student verification
- Enhances trust, transparency, and efficiency
- Encourages digital adoption in governments and academic institutions

Future scope

- AI-based anomaly detection for suspicious certificates
- Multi-language support for international students
- Offline verification via blockchain + IPFS hybrid
- API for cross-institution interoperability globally
- Integration with government portals like DigiLocker

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Full Length Article

IJCRAR/FL/132

Cloud Computing: The Future of Computation and Service Delivery

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Abstract

Cloud computing has emerged as a transformative paradigm in modern information technology, enabling on-demand delivery of computing resources and services over the Internet. By providing scalable infrastructure, flexible platforms, and ready-to-use software applications, it has redefined the way organizations and individuals consume computational power. This paper presents a comprehensive study of cloud computing, highlighting its definition, evolution, essential characteristics, service delivery models, and deployment approaches. The benefits of cloud computing, such as cost efficiency, scalability, flexibility, and innovation acceleration, are analyzed alongside its challenges, including security, privacy, compliance, and service dependency. Furthermore, the paper explores diverse real-world applications in business, education, healthcare, entertainment, and government sectors. Finally, future trends such as artificial intelligence integration, edge computing, quantum processing, and sustainable cloud infrastructures are discussed. Through this analysis, the paper emphasizes that cloud computing is not merely a technological trend but a foundational component of the digital ecosystem that will continue to shape industries, economies, and societies.

Keywords: Cloud Computing, Service Delivery Models, Scalability, Security Challenges, Future Trends

Introduction

In the last two decades, the field of computing has experienced a paradigm shift. Organizations and individuals have moved away from traditional on-premises infrastructure toward service-based and Internet-driven solutions. This new model is known as Cloud



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Computing. Cloud computing delivers shared computing resources such as storage, processing power, and software applications over the Internet. Instead of owning hardware and software outright, users can access computing services on-demand, similar to how electricity or water is consumed. This paper presents a comprehensive study of cloud computing, covering its characteristics, service and deployment models, benefits, challenges, applications, and future scope.

Definition and Evolution of Cloud Computing

Definition

Cloud computing can be defined as “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (such as networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or provider interaction” (NIST Definition).

Evolution

1960s: John McCarthy predicted that computing would someday be delivered as a utility.

1990s: The advent of the Internet and distributed systems laid the foundation.

2000s: Amazon, Google, and Microsoft launched cloud-based services, popularizing the concept.

Today: Cloud is integral to artificial intelligence, big data analytics, mobile applications, and global business processes.

Essential Characteristics of Cloud Computing

According to standard definitions, cloud computing exhibits the following fundamental characteristics:

1. On-Demand Self-Service: Users can provision computing capabilities automatically, without human interaction.
2. Broad Network Access: Services are accessible through standard mechanisms over the Internet.
3. Resource Pooling: Computing resources are pooled to serve multiple customers dynamically.



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4. Rapid Elasticity: Capabilities can be elastically scaled outward or inward, depending on demand.
5. Measured Service: Resource usage is monitored, controlled, and reported to provide transparency.

Service Delivery Models

Cloud computing services are categorized into three primary service models:

Infrastructure as a Service (IaaS)

Provides virtualized computing resources over the Internet.

Users can rent servers, storage, and networks without owning physical infrastructure.

Example: Amazon EC2, Google Compute Engine.

Platform as a Service (PaaS)

Offers an environment for developers to build, test, and deploy applications.

Users focus on development while the provider manages the infrastructure.

Example: Microsoft Azure, Google App Engine.

Software as a Service (SaaS)

Provides access to ready-to-use applications hosted on the cloud.

Examples include Gmail, Dropbox, and Microsoft 365.

Deployment Models

Cloud computing can be deployed in various forms, depending on user requirements:

1. **Public Cloud:** Infrastructure owned and operated by third-party providers.
2. **Private Cloud:** Dedicated infrastructure for a single organization, providing better control and security.
3. **Hybrid Cloud:** Combination of public and private cloud to achieve flexibility.
4. **Community Cloud:** Shared by several organizations with common objectives.

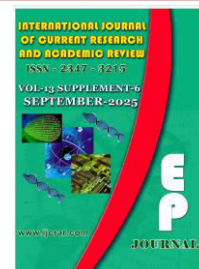


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Advantages of Cloud Computing

Cloud computing offers several benefits, making it one of the most adopted technologies worldwide:

Cost Efficiency: Reduces capital expenditure on hardware/software.

Scalability: Services can be scaled up or down instantly.

Flexibility: Access services from any device, anywhere.

Business Continuity: Provides data backup and disaster recovery

Innovation Acceleration: Enables faster development and deployment of applications.

Challenges and Limitations

Despite its advantages, cloud computing faces certain challenges:

Security and Privacy: Data stored on third-party servers is vulnerable to breaches.

Downtime Risks: Service outages may interrupt critical operations.

Limited Control: Organizations depend heavily on service providers.

Compliance Issues: Different regions have varying legal and regulatory requirements.

Applications of Cloud Computing

Cloud computing finds applications in multiple domains:

Business Enterprises: Customer relationship management (CRM), enterprise resource planning (ERP).

Education: Online learning platforms, virtual classrooms, research collaboration.

Healthcare: Storage of medical records, telemedicine, diagnostic support.

Entertainment: Online gaming, music/video streaming (Netflix, Spotify).

Government: E-governance, smart city initiatives.

Future of Cloud Computing

The future of cloud computing lies in integration with emerging technologies:

Artificial Intelligence and Machine Learning: Cloud platforms will provide scalable AI services.

Edge Computing: Combining cloud with edge devices to reduce latency.



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Quantum Computing: Cloud providers may deliver quantum processing as a service.

Green Cloud: Focus on sustainability and energy-efficient data centers.

Cloud computing will continue to evolve, shaping industries and lifestyles in the digital era.

Conclusion

Cloud computing represents a revolutionary model of delivering IT services. With its flexibility, scalability, and cost-effectiveness, it is becoming the backbone of modern businesses, education, healthcare, and governance. However, organizations must address challenges related to security and compliance to ensure its sustainable growth.

In conclusion, cloud computing is not merely a technology trend but the future of digital infrastructure, transforming the way we compute, communicate, and collaborate.

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Full Length Article

IJCRAR/FL/133

Applications and Operations of Cloud Computing

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Abstract

Cloud computing has emerged as a transformative technology that fundamentally changes the way individuals, businesses, and organizations access, manage, and utilize computing resources. By providing scalable, on-demand access to processing power, storage, networking, and applications over the internet, cloud computing eliminates the need for heavy investment in on-premises infrastructure and reduces operational complexity. Its applications are diverse and far-reaching, ranging from data storage, backup, and disaster recovery to software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS). These applications enable organizations to deploy applications rapidly, facilitate remote collaboration, and access enterprise-grade computing resources without geographic limitations. In terms of operations, cloud computing relies on advanced technologies such as virtualization, resource pooling, and automated provisioning to optimize resource utilization and maintain high performance. Key operational benefits include dynamic scalability, high availability, load balancing, and efficient management of workloads, which are critical for handling fluctuating demand and large-scale data processing. Cloud environments also support advanced analytics, artificial intelligence, and machine learning applications, allowing organizations to extract actionable insights from vast amounts of data in real time. Moreover, cloud computing enhances business continuity and security through redundancy, backup, and centralized management of security policies. Overall, the applications and operations of cloud computing provide a flexible, cost-effective, and innovative framework that drives digital transformation and empowers organizations to achieve greater agility, efficiency, and competitiveness in an increasingly connected world.

Keywords: Cloud Computing, Virtualization, Scalability, SaaS–PaaS–IaaS, Digital Transformation

Introduction

Cloud computing has emerged as one of the most transformative technologies of the digital era, providing on-demand access to computing resources such as servers, storage, databases, networking, and software through the internet. Its applications span across almost every sector, making it a backbone for



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modern innovation. In business, cloud computing enables enterprises to host applications, manage customer data, and deploy scalable solutions without investing heavily in physical infrastructure. It supports advanced technologies like artificial intelligence, big data analytics, and the Internet of Things, driving smarter decision-making and real-time insights. Cloud-based applications are also revolutionizing healthcare, education, finance, and e-commerce by offering secure, cost-efficient, and globally accessible solutions. Alongside its wide applications, the operations of cloud computing ensure that these services run smoothly and reliably. Cloud operations involve provisioning resources, automating deployment, managing performance, monitoring security, ensuring data backup and disaster recovery, and optimizing costs. With tools for identity management, compliance, and continuous monitoring, cloud operations guarantee availability, scalability, and resilience of services while reducing downtime and enhancing user experience. Together, the applications and operations of cloud computing are shaping a future where technology is more accessible, efficient, and adaptable to the evolving needs of individuals and organizations worldwide.

Literature Review

The literature on cloud computing highlights its transformative role in delivering scalable, cost-effective, and flexible computing services across various domains. Several studies have emphasized the wide range of cloud applications, including education, healthcare, business, and entertainment, where cloud platforms enable online learning, electronic health records management, enterprise resource planning, and real-time content distribution. Researchers have also examined operational aspects of cloud computing, focusing on resource provisioning, virtualization, automation, and performance optimization to ensure reliability and scalability of services. Security and privacy concerns remain a central theme in existing works, with studies proposing frameworks for identity management, encryption, intrusion detection, and compliance with regulatory standards. Additionally, related works have explored disaster recovery mechanisms, backup strategies, and cost management practices to improve operational efficiency. Recent literature further highlights the integration of emerging technologies such as AI, IoT, and edge computing with cloud platforms, enhancing both applications and operations. Overall, prior research underscores the importance of cloud computing as a backbone for digital transformation, while identifying challenges in security, cost optimization, and sustainability as areas for future exploration.

Tools For Creating Cloud Computing

1. Amazon web services (AWS):

A comprehensive suite of services offering scalability and reliability for various business needs.

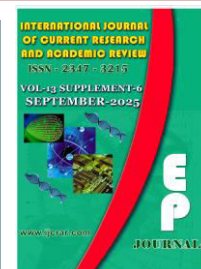


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2. Microsoft Azure:

A strong choice for enterprises, particularly those with windows-based systems.

3. Google cloud platform (GCP):

Known for its data analytics and machine learning capabilities

Purpose of Cloud Computing

The primary purpose of cloud computing is to provide on-demand, scalable, and flexible access to computing resources over the internet, eliminating the need for organizations and individuals to rely heavily on physical hardware and traditional IT infrastructure. It aims to reduce costs associated with purchasing, maintaining, and upgrading servers, storage devices, and networking equipment while providing a pay-as-you-go model that enhances financial efficiency. Cloud computing also enables rapid deployment of applications and services, supporting business agility and innovation.

Additionally, cloud computing facilitates seamless collaboration by allowing users to access data and applications from anywhere at any time, improving productivity and enabling remote work. It ensures high availability, reliability, and disaster recovery through redundant systems and centralized management, which minimizes downtime and data loss. Furthermore, cloud platforms support advanced technologies such as big data analytics, artificial intelligence, and machine learning, allowing organizations to process large datasets efficiently and gain actionable insights. Overall, the purpose of cloud computing is to provide a flexible, cost-effective, and secure IT environment that empowers organizations to focus on their core operations while leveraging advanced computing capabilities.

Applications Of Cloud Computing

1. **Education** – Online learning platforms, virtual classrooms, and e-libraries are powered by cloud infrastructure.
2. **Healthcare** – Patient record management, telemedicine, and collaborative research rely on secure cloud storage.
3. **Business** – Cloud services streamline customer relationship management (CRM), supply chain management, and e-commerce.
4. **Entertainment** – Streaming platforms such as Netflix and online gaming use cloud for content delivery and real-time scalability.
5. **Research and Development** – Scientists use cloud for big data analysis, simulations, and collaborative projects.

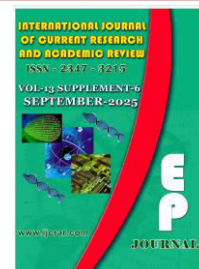


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Operations Of Cloud Computing

Cloud operations refer to the processes and technologies that ensure smooth delivery of services. Major operations include:

- **Virtualization:** Enables multiple virtual machines to run on a single physical machine.
- **Resource Pooling:** Shared resources are dynamically allocated to multiple users.
- **Elasticity and Scalability:** Systems automatically scale up or down based on demand.
- **Measured Service:** Pay-as-you-go billing ensures cost efficiency.
- **Security Management:** Authentication, encryption, and access control ensure data protection.

PROS and CONS

PROS

- **Cost Efficiency:** Reduces the need for physical infrastructure.
- **Flexibility:** Access services from anywhere at any time.
- **Scalability:** Handles varying workloads with ease.
- **Collaboration:** Enhances teamwork through shared platforms.
- **Backup and Recovery:** Provides disaster recovery solutions.

CONS

- **Security Risks:** Data breaches and privacy concerns.
- **Downtime:** Internet dependency may cause disruptions.
- **Compliance Issues:** Regulatory challenges in data storage.
- **Vendor Lock-In:** Difficulty in migrating between providers.
- **Hidden Costs:** Long-term operational costs may rise.

Conclusion

Cloud computing has transformed the way data, applications, and services are delivered, offering unmatched scalability, flexibility, and cost efficiency. Its wide-ranging applications in education, healthcare, business, entertainment, and research highlight its potential to simplify operations and enhance productivity. Core operations such as virtualization, resource pooling, and elasticity ensure seamless service delivery, while measured services support transparency and cost savings. However, challenges such as data breaches, downtime, vendor lock-in, and compliance with data regulations cannot be overlooked. Addressing these issues through stronger security frameworks, transparent service agreements, and hybrid or multi-cloud approaches is vital. By overcoming these challenges, cloud



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computing will continue to empower organizations and individuals, fostering global connectivity, collaboration, and innovation. As technology advances, the adoption of cloud services will only increase, playing a critical role in shaping the digital future and supporting the next generation of technological growth.

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Full Length Article

IJCRAR/FL/134

Genetic Susceptibility to Autoimmune Diseases: An Extensive Review of Variants

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Abstract

The pathways leading to autoimmune illnesses have become more visible in recent years thanks to our growing understanding of the genetic origins of complicated human disease and our deep understanding of the human immune system. The PTPN22 gene may play a key role in immunological dysfunction development as it encodes a protein tyrosine phosphatase that is produced by most cells in both adaptive and innate immune systems. Complex genetic disorders resulting from a combination of hereditary and non-genetic risk variables are commonly observed in Autoimmune Diseases (ADs) including Multiple Sclerosis (MS), Systemic Lupus Erythematosus (SLE) and Rheumatoid Arthritis (AR). Numerous immunological processes have been demonstrated to be severely disrupted by gene variations, especially single nucleotide polymorphisms (SNPs). We provide an overview of the mechanism by which PTPN22 and its inherited variations contribute to the pathogenesis of autoimmune disorders in this article. We go over the developments in our knowledge of how PTPN22 affects autoimmunity in humans in this review. Furthermore, we point out the pathogenic relevance to the PTPN22 gene, focusing specifically on its involvement in T and B cells as well as innate immune cells such monocytes, dendritic cells and killer cells. A thorough understanding of these results will enable us to make sense of the complex genetics of autoimmunity, as well as contribute to the creation of new medications and the criteria used to diagnose and prognosticate the illness.

Keywords: Autoimmune Diseases (ADs), PTPN22, Multiple Sclerosis (MS), Systemic Lupus Erythematosus (SLE) and Rheumatoid Arthritis (AR), single nucleotide polymorphisms (SNPs).

Introduction

Autoimmune illnesses are diverse conditions marked by aberrant immune reactions directed against the tissues of the organism, resulting in persistent inflammation. One of the



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biggest genetic risks for the development of autoimmunity is currently known to be the presence of the protein tyrosine phosphatase non receptor 22 (PTPN22) gene. In humans, this gene produces the 110 kDa protein known as lymphoid tyrosine phosphatase (LYP), also known as PTPN22. Since the exact aetiology of autoimmune illnesses is unknown, medical professionals have proposed a number of explanations, including hereditary, environmental, and other variables including infection. Finding the genetic variations and genes linked to the diseases has been made possible by recent developments in the fields of genetic epidemiology and Genome-Wide Association (GWA) studies. Some prevalent genes are known to have a high correlation with autoimmunity since most autoimmune illnesses share comparable clinical characteristics. Analyzing these shared genes' properties can provide hints for diagnosing illnesses whose causes is unknown.

The majority of PTPN22 expression occurs in cells of hematopoietic origins. According to the family history and conditions of experimentation, PTPN22 may either stimulate or prevent autoimmune. The emergence of autoimmune disorders is primarily linked to the single nucleotide polymorphism (SNP) PTPN22 C1858T (rs2476601) in exon 14. The amino acids at codon 620 (R620W) changed from arginine to tryptophan due to an alteration with cytosine to thymidine at nucleotide 1858. The creation and inactivation of T-cell receptor-associated kinases and their associated substrates, as well as avoiding the occurrence of spontaneous T cell activation, are all facilitated by the Lyp protein. Genetic association studies were used to evaluate the early functional effects of PTPN22 in autoimmune diseases. Type 1 diabetes mellitus, Rheumatoid Arthritis (RA) and Systemic Lupus Erythematosus (SLE) were found to be particularly associated with one missense single nucleotide polymorphism (C1858T, rs2476601). However, a number of studies have demonstrated the existence of the 1858T allele offers protection against a number of different viral and inflammatory illnesses. Indeed, it has been discovered that individuals with the 1858T allele are shielded against serious infections caused by bacteria [1] and pulmonary tuberculosis. The PTPN22-1858T variant may play a broad function in boosting immunological responses, as evidenced by its relationship with a variety of immune diseases [2]. Nevertheless, the precise process by which the C1858T polymorphism influences PTPN22 function is intricate. Depending on the cellular environment and signaling pathways, both gain- and loss-of-phosphatase activity effects have been proposed. An example of a systemic autoantibody-mediated autoimmune illness is lupus or SLE. In lupus, the generation of autoantibodies results in multisystem tissue damage through both direct autoantibody target tissue destruction and indirect



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autoantibody-autoantigen (immune) complex creation and deposition. Genetic investigations hold considerable promise for identifying pathways of signaling that are probably involved in the development of lupus. Functional biologists use genetic association data to formulate hypothesis-driven queries that help them understand the underlying causes of disease. We present the numerous genomic areas that have been linked to lupus in this review. Next, we talk about how the genes that are thought to be involved collaborate in common pathways of signaling and are frequently mixed

Relationships Between PTPN22 C1858T and Autoimmune Diseases

Relationship between Type 1 Diabetes & PTPN22 C1858T

It was initially established by Bottini et al. [3] that the PTPN22 R620W polymorphism and T1DM are related. The 1858T allele is subsequently validated by Heneberg et al. to function as a risk gene causing latent autoimmune diabetes in adults (LADA). Additionally, they verified that there is gender-based variations in the incidence of a few PTPN22 polymorphisms in LADA. Observational studies yielded 22 comparisons; of them, 19 (86.4%) had significant results. According to research by the Habib group, the Lyp R620W variation influences periphery B cell homeostasis in heterozygous controls who are healthy by encouraging a particular growth of the CD27⁺, IgD⁺, IgM⁺, and B cell populations, as well as transitional and anergic B cell populations [4]. In addition, they observed that T1DM patients, regardless of the PTPN22 genotype, had decreased B cell receptor signaling & resistance to death of cell in both the transitional and newborn B cell divisions. It's interesting to note that PTPN22 affects T1DM by modifying Treg cells. Utilizing PTPN22 knock-out mice in both in vitro and in vivo tests, it was demonstrated that PTPN22 is essential for Treg induction and primarily functions by adjusting the T cell activation threshold. Surprisingly, some research on animal models revealed PTPN22 may have a preventive function in type 1 diabetes. In addition to shielding animals against a diabetic condition, overexpression of PTPN22 reduced Th1 differentiation at low strength T cell receptor (TCR) activation. NOD mice that had their PTPN22 expression knocked down genetically were shielded against autoimmune diabetes. Due to PTPN22's dominating influence on Treg cells, T1DM was prevented in NOD mice when PTPN22 was knocked down [5]. The number and functioning of Treg cells rise in response to a decrease in PTPN22 levels, as demonstrated in multiple mice models with different genetic backgrounds [5]. Human studies revealed that the PTPN22 variation



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significantly increased the incidence of T1DM; nevertheless, a meta-analysis revealed a protective impact. Re-examining earlier findings with Bayesian methods accomplished does not validate this exception, hence one of the meta-analysis's potential shortcomings could apply to this study [6]. Overall, the findings indicated that the PTPN22 620W variation in T1DM carries a sizable risk.

Link of "PTPN22 C1858T & Rheumatoid Arthritis"

Aside from the HLA genes, the PTPN22 gene is a key genetic component in the development of rheumatoid arthritis (RA). Begovich et al.'s landmark 2004 work established the first clear association among the PTPN22 1858T gene & RA [7]. Patients who have the homozygous PTPN22 1858C's variation were twice as likely to develop RA as those with the 1858T version, indicating a co-dominant allele association [7]. In RA, studies show that the PTPN22 risk allele has a dose-dependent effect. Numerous studies have looked into the relationship between the PTPN22 variation and both the chance of getting RA and its clinical features. The PTPN22R620W allele is believed to be linked to seropositive disorders, the existence of antibodies against citrullinated proteins (ACPA), damaging circumstances, and an earlier onset of disease. Most research demonstrate that carrier of the PTPN22 1858T gene develop RA at a younger age, often between 2 and 7.5 years sooner, while certain investigations have not consistently proven this effect. Variations in the design of experiments and techniques have resulted in inconsistent outcomes. A re-evaluation of earlier findings using Bayesian techniques found that the vast majority of comparison from observational research and one GWAS meta-analysis yielded significant results based on FPRP or BFDP [6]. Genetic changes in PTPN22 may trigger RA via a variety of methods. Reduced PTPN22 function may result in extended activation of particular CD4+ T cells along with additional effector T cells, promoting synovial inflammation [8]. In models of mice, PTPN22 has been found to modulate autoantigen absorption and presentation mediated by vimentin-dectin-1, in addition to cytokine release. Autoantibodies targeting citrullinated vimentin, that are frequent among RA patients, have been shown to promote osteoclastogenesis & bone resorption. When Toll-like receptors (TLRs) stimulate cells in the human body, the PTPN22 Trp620 variation causes insufficient interferon (IFN) production. When PTPN22 is not working properly, T-cell receptors (TCRs) are more likely to activate. Mice bred to have a human PTPN22 Trp620 variation had difficulty recovering from arthritis after receiving a TLR activator that typically raises IFN levels [9]. This model of inflammation in joints relies on IL-1 β . The autoimmune process connected to the PTPN22 1858T variation likely involves a mix of issues, including irregularities with the way



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different types of T cells mature, alterations in the variety of B cells, and adjustments in the balance among immune-suppressing as well as inflammation-promoting cytokines.

Systemic Lupus Erythematosus & PTPN22 C1858T" mutation

Kyogoku et al. (2004) identified the PTPN22 1858T variant as associated with SLE [10]. A case only GWAS analysis linked PTPN22 1858T to seropositive SLE, whereas another study identified a positive correlation between anti-cardiolipin IgG and a higher incidence of PTPN22 1858T among people with lupus nephritis or seropositive to anti-dsDNA autoantibodies [10]. SLE can be caused by immune complex deposition & antibody-mediated effects. SLE comprises a systemic inflammation that produces autoantibodies, forms immune complexes, and deposits them in organs. The PTPN22 1858T variant has been linked to both lower and greater IFN- γ concentrations in SLE. Dysfunctional IFN- γ release in SLE can lead to enhanced "IFN- α -mediated JAK-STAT" signaling among people with the 1858T danger mutation. Pep & IFN- γ may interact, causing impaired haematopoiesis. The PTPN22*W mutation has been shown in animal models to affect TCR signaling, potentially enhancing early processes including protein tyrosine phosphorylation & calcium mobilization. Previous research indicates that anti-CD3 monoclonal antibodies (mAbs) stimulate TCR signaling in SLE. Furthermore, greater PTPN22 gene concentrations in CD 8+ T cells were associated with negative outcomes for SLE patients & AAV [11].

Association of "PTPN22 C1858T with Autoimmune Thyroid Disorder"

Aside from Type 1 diabetes, Rheumatoid Arthritis, Systemic Lupus Erythematosus as well as additional autoimmune conditions, there are additionally autoimmune thyroid disorders (AITD) like Grave' & Hashimoto's, Addison's syndrome, chronic thrombocytopenia, & bowel inflammation. The "PTPN22 1858T" variant was found to be significantly associated with vitiligo and other conditions. A systematic review revealed that "PTPN22 C1858T" raises the chance of Grave's syndrome & Hashimoto's thyroid infection among people of all ages. This genetic variation elevates the risk of AITD in Caucasians compared to those among Asians [12]. A study of 211 Korean AITD cases discovered that a single SNP variant "rs12730735" and a variant of the haplotype "GGCTT" were substantially related with vulnerability to AITD, particularly in instances of thyroiditis associated with Hashimoto's [12]. Gong et al. found an uncommon



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missense mutation within PTPN22 (NM_015967.5; c.77A > G; p.Asn26Ser) in Chinese AITD patients with Hashimoto's thyroiditis using whole-exome sequencing. However, the "PTPN22 C1858T" variant has not been verified [13].

Link of "PTPN22 C1858T with Autoimmune Skin Diseases"

The investigation discovered a strong link between psoriatic arthritis and a genetic mutation known as "PTPN22 C1858T". Patients with this genetic variant were found to have a greater risk of acquiring psoriatic arthritis, having a risk ratio of 1.49. Furthermore, the study discovered that these people had a higher prevalence of joint abnormalities than those lacking this genetic mutation. This shows the fact that the "PTPN22 C1858T" variation may be involved in the formation and advancement of psoriatic arthritis, with it potentially contributing to the joint abnormalities observed in affected patients [14]. However, the majority of vulnerability genes in psoriasis (PsO) are similarly related with skin psoriasis & PsA, the 1858T variant PTPN22 has a weak association to general skin psoriasis but a strong association with PsA [14]. PTPN22 may impact several cells & pathways in PsA, a condition with a more complex aetiology than skinrestricted conditions. According to Bowes et al., the connection of PTPN22 Trp620 to PsA vs. PsO is due to changes in CD8 T cell function, which is regulated by PTPN22 [14]. The involvement of PTPN22 across CD 8 memory T cell activity & "IL-17-producing Th17 cell" formation implies that PTPN22-W620 may contribute various Th17 morphologies in psoriatic arthritis (PsA), psoriasis (PsO), and ankylosing spondylitis (AS). The transcription factor T variant associated with the singular nucleoid polymorphisms (SNP) "rs2476601" within PTPN22 genes increases the likelihood of developing alopecia areata. However, further robust investigations identifying the ethnic composition of the population's country of origin must be conducted in order to validate the risk determined by the current study [15].

PTPN22 C1858T with Other Autoimmune Conditions

The allele appears to protect against Crohn's disorder (CD) & Behçet's disorder [16]. Yet, the findings were not based on big samples, and while there were a few instances, the relationships failed to repeat. In one research (two comparisons) of BD along with a study (three comparison) of AITD, neither FPRP nor BFDP yielded significant results [6]. There is no link among "rs2476601" & auto immune diseases involving the liver's cells & bile tubes include



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immune-mediated hepatitis, primary cholangitis of the bile ducts and primary sclerosis cholangitis. However, more research would be required due to a limited number of studies. Unlike in RA research, the presence of autoantibodies does not impact the link with systemic sclerosis (SSc). A meta-analysis found no variation within frequency of alleles while evaluating Individuals who test positive for anti-centromere antibodies might be negative for serology and positive for antitopoisomerase I autoantibodies or have systemic sclerosis (SSc) despite negative autoantibodies. Two distinct research used Bayesian approaches to analyses the genome's influence on psoriasis (PsO) using three genetic correlations & found no significant results using FPRP or BFDP estimates [6]. Three studies on patients with SSc found no significant differences in FPRP and BFDP estimates across seven genotypic and allelic comparisons. There were only two studies on patients with SS & AS, and FPRP and BFDP calculations were not used to establish their significance. Several research have attempted to understand the functional role of PTPN22 in CD. PTPN22, which modulates intracellular signaling, is activated via IFN- γ by human monocytes [17]. PTPN22 knockdown changes the stimulation of inflammatory signaling transducers, resulting in increased secretion of Th17- related mediators of inflammation. This could explain how lower PTPN22 expression in CD patients contributes to the disease's pathogenesis. Spalinger et al. found that CD patients have higher TNF α levels, which decreases PTPN22 expression considerably. This suggests that TNF α may play a more significant part in CD pathogenesis than IFN- γ . The C1858T polymorphism, which results in a gain of function, has been found to be protective in CD and reduce the production of proinflammatory cytokines [18].

Variations in the PTPN22 locus linked to Autoimmune Conditions

The C1858T variations, as well as other PTPN22 genetic variations, are being linked to autoimmune ailments particularly in populations with low frequency of the C1858T polymorphism. These associations are more prominent in Asian populations, indicating the complexity of most autoimmune diseases. A systematic search for SNPs in the PTPN22 gene identified five SNPs, with two SNPs showing allele frequencies of over 5%. The G1123C polymorphism (rs2488457) is a non-coding SNP found in the 50- promoter region of PTPN22, associated with RA, JIA, acute T1D. The 788A allele in PTPN22, a protein with a unique autoimmune disease association, is distinct from the 1858T allele in European populations due to a rare missense G788A mutation that encodes an R263Q substitution in the protein's catalytic domain, resulting in reduced catalytic activity. The 788A allele, unlike the 1858T allele, provides



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protection against both SLE and RA. Studies have examined the link between ethnicity and susceptibility to autoimmune diseases. A Japanese study indicated that insignificant polymorphisms encoding "rs1217412", "rs1217388", "rs1217407" & "rs2488458" were fewer in chronic patients with hepatitis than in controls. A genome-wide association study found PTPN22 not related to European autoimmune hepatitis patients. A Chinese Han population study found strong associations between SLE and RA, while rs3765598 had a significant association with SLE.

Diseases	Functions of the Immune System
T1DM	- The PTPN22 variant raises the amount of autoreactive B cells in the body, which promotes autoimmune responses via delivering autoantigens in T lymphocytes. - T1DM individuals having PTPN22 mutations, B cell growth, reduced receptor signaling, and resistance to apoptosis are observed. - The 1858T variant disrupts B cell homeostasis and Toll-like receptor 9-mediated response, and cytokine production. - The PTPN22 mutation boosts Treg cell & alters activation of T cells thresholds. Amplification of PTPN22 suppresses TCR-mediated responder cells feedback, hence preventing the autoimmune process.
RA	- The absence of PTPN22 function triggers the activation of antigen specific CD4+ and effector T cells, accelerating the progression of RA. - Increased antibody production also promotes osteoclastogenesis and bone resorption. Human cells expressing PTPN22 Trp620 lack TLR-induced IFN production.
SLE	- The "C1858T PTPN22" variation increases the possibility for SLE by decreasing IFN-gamma & increasing plasma IFN-alpha production. - This Variation might boost IFN-alpha-mediated JAK-STAT activity, leading to dysfunctional hematopoiesis. - The PTPN22*W polymorphism influences TCR signaling and promotes autoimmunity, with patients with SLE showing abnormalities in TCR/CD3 monoclonal antibody stimulation.

Table 1 PTPN22 C1858T polymorphism association with various types of autoimmune disease

Conclusion

Finally, single nucleotide polymorphisms (SNPs) in the PTPN22 gene play an important role in the development of autoimmune disorder that are "Type 1 Diabetes Mellitus (T1DM)", "Rheumatoid Arthritis (RA)", "Juvenile Idiopathic Arthritis (JIA)", "Psoriatic Arthritis (PsA)",



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"Systemic Lupus Erythematosus (SLE)", "Systemic Sclerosis (SSc)" & "Autoimmune Thyroid Diseases (AITD)". These SNPs are important genetic variables that influence the vulnerability and development of autoimmune diseases. Not only the PTPN22 C1858T SNP, but also new variants in genes like CTLA4, TNF, and IRF5 have been linked to autoimmune disorders. Large-scale GWAS studies support the importance of genetic factors in autoimmunity, but further research is needed to confirm these findings. This polymorphism has been associated with modified immune system function & increased vulnerability to autoimmunity. It causes a missense variant (R620W) within the PTPN22 gene. The PTPN22 mutation has been linked to autoimmune reactions in T1DM through altered activated T cell threshold, higher autoreactive B cells, and disturbed B cell homeostasis. Comparably, in RA, antigenspecific CD4+ and functional T cells become activated when PTPN22 activity is disrupted, which encourages synovial inflammation & bone resorption. Furthermore, the C1858T polymorphism raises the risk of SLE via modifying IFN-gamma levels and improving IFN-alpha-mediated signaling, which in turn leads to autoimmunity and defective hematopoiesis. Additionally, correlations have been documented among PTPN22 polymorphisms and various additional autoimmune conditions, including vasculitis, autoimmune thyroid disorders, as well as autoimmune skin diseases. Although some research indicates that specific PTPN22 variants may offer protection against autoimmune diseases such as Crohn's disease along with Behçet's disease, the overall effect of PTPN22 polymorphisms on the susceptibility to autoimmune diseases highlights the intricate interaction among genetic, environmental, and immune factors in the development of autoimmunity. To summaries, that PTPN22 C1858T polymorphism influences immune system function & signaling pathways, which in turn predisposes people to a variety of autoimmune disorders. The development of focused treatment approaches and important insights into the pathophysiology of autoimmune disorders may result from more investigation into the functional processes underpinning these relationships.

Future Scope

Research concerning the PTPN22 C1858T mutation including its connection to autoimmune illnesses opens up a number of possibilities for further investigation and possible advancements. Further research into the exact functional mechanisms that determine how a PTPN22 C1858T polymorphism affects immune system function is one important topic. Comprehensive molecular and cellular investigations may be necessary to clarify the polymorphism's subsequent impacts affecting immune cell signaling systems & cytokine



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production. Furthermore, it is crucial to investigate any connections that might exist among PTPN22 polymorphisms and additional genetic variations linked to autoimmune disorders. Gene expression profiling and GWAS, or genome-wide association studies, may be able to reveal the genetic networks and pathways connected to autoimmune. Large-scale population studies conducted among a variety of ethnic groups may shed light on the variability of disease and guide the development of customized treatment strategies. Furthermore, converting research results into clinical applications through the creation of prognostic markers and diagnostic tools based on PTPN22 mutations may make it possible to identify people at high risk of autoimmune diseases early on and enable focused interventions to stop the onset or progression of the disease. Another important line of inquiry is the therapeutic potential for addressing PTPN22 alongside other signaling pathways towards the management of autoimmune disorders. By analyzing the molecular mechanisms behind PTPN22-mediated autoimmunity on the single-cell level using state-of-the-art functional genomics technologies, like CRISPR/Cas9 gene editing & single-cell sequencing, new treatment targets and autoimmune disease biomarkers may be discovered. Ultimately, a thorough grasp of the intricate interactions among genetic, environmental, and immunological components in autoimmunity will require the integration of multimaps data, including genomes, transcriptomics, proteomics, and metabolomics. All things considered, more investigation into the function of PTPN22 polymorphisms with autoimmune disorders has the potential to improve our comprehension of illness etiology and create useful diagnostic, prognostic, and treatment approaches

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Full Length Article

IJCRAR/FL/130

Smart Banking Chatbot

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Abstract

The purpose of the project is to make any domain-specific website, in our case banking, more usable by integrating a chatbot that serves as an interface for customer inquiries about services. This reduces customer interaction time with websites, thereby valuing their time and improving their overall experience. As part of this project, we explored and attempted to create an intelligent chatbot that could extract relevant information, recognize various intents and execute the pre-mapped actions. To create a contextual assistant for the above purpose, we used the RASA framework. To train the model, we constructed a custom dataset that includes multiple intents and entities. Additionally, we provide some python scripts (RASA actions) that will be executed when some intents are detected. Our solution consisted of creating a pipeline having a chatbot and several actions triggered by the chatbot. These actions will connect with the database and then provide the required data or make changes according to the user's query and display the feedback back to the user via the chat widget.

Keywords: Chatbot, RASA Framework, Natural Language Processing, Banking Services, Customer Experience

Introduction

At a very basic level chatbot can be considered to be an agent which can interact with a user like a human (voice or text) and understand what the user wants from it and provide a specific set of services to the user according to the user's demands. Chatbot also acts as an information-gathering tool using which the organization can know their customer base more clearly and understand their needs. Chatbots are used in a wide range of domains right from health care services to customer relationship management services.



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A chatbot broadly comprises three subsystems which are Natural Language Understanding(NLU) which understands what the user is trying to communicate or what is the intent of the provided sentence, Dialog Management which maintains the state of communication by remembering what key pieces of information have been provided by the user and how to drive the conversation ahead and Natural Language Generation(NLG) which handles the part where the chatbot figures out what the bot should respond to back to the user. RASA is an open-source Natural Language Processing(NLP) tool that is used to build virtual assistants and contextual chatbots. RASA provides two main modules Rasa Open Source and Rasa Action Server. Rasa Open Source has Rasa NLU to recognize the intent of communication and Rasa core to decide what to do next and how to proceed with the conversation. Rasa Action Server allows the hosting of Python scripts to perform certain custom tasks like processing or modifying databases in the backend. This paper presents a chatbot deployed on a banking website that offers certain services like checking account balance, making a transaction, and many more to users right in the chat window.

Literature Survey

This paper [1] presents the use of the RASA framework for building smart context remembering chatbots, it also describes how Rasa NLU works and how its performance is elevated by using intent recognition and entity extraction. It also compares the accuracies of entity extraction using Rasa NLU and a NN, results show Rasa NLU performs better to extract entities when whole sentences are provided as compared to neural networks which require segmented inputs. This paper discusses Rasa by implementing a chatbot related to the finance domain, using which the users can inquire about stock-related information.

RASA NLU can introduce a vital component in intelligent chatbot systems. We can compose the system to extract the entity after intent recognition. This can be further improved for complicated sentences and more entities.

This paper [2] briefly discusses advancements in the field of AI and how this has led to major shifts in some organizations about how they operate. It further mentions how the banking industry has moved to use chatbots for providing an interface to customers so that they can have an assistant throughout the day for service. This paper also gauges the ability of current chatbots to provide all the services that a user needs.



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It includes several strategies for managing dialogue in the banking and finance industry based on ontology. Although further use of AI can make the chatbot not only respond to questions but also self-learning to improve itself in more stages, improving user service quality and also reducing human load.

Proposed System

A. Problem definition

Technology use in today's banking sector continues to be high, pushed by the ever-increasing need for more banking services. In the competitive banking area, the customer expects quick responses increasing the load for banks to catch up with the requirements.

This project aims to develop a website with a chatbot that is not only capable of having conversations with the customer but also has the ability to listen to commands and make changes to the database

B. Dataset

The custom dataset is created which contains in total of thirty-six intents out of which twenty are domain-specific intents these are the ones that are related to common banking queries and sixteen intents are written for basic utterances while in a conversation. Dataset consists of eleven entities(transaction_amount, email_id, location, phone_no, etc) that can be recognized by the model and will further be stored in slots which in turn will drive the conversation. For domain-specific intents, on average approximately fifteen examples are provided per intent. Here are some of the example sentences from the intent 'pin_change':-

- 1) I would like my pin to be [6711](pin);
- 2) set pin to [6665](pin);
- 3) I want my new pin to be [1234](pin);
- 4) pin change;

C. Technology Used

- 1) Chatbot Framework: RASA



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- 2) Website backend: Django
- 3) Frontend: HTML5, CSS/Bootstrap, JavaScript
- 4) Database: PostgreSQL

Project Architecture

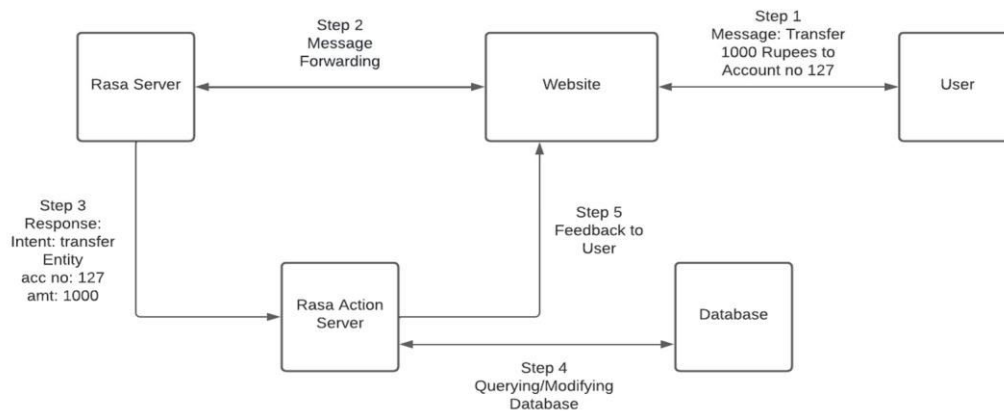


Fig. 1 This figure represents basic blocks of the whole system consisting of chatbot, website and database and how communication occurs between them.

As shown in Fig. 1, firstly the user will provide a message on the website through the chat window, this message will be passed over to the RASA server by the website. The Rasa server will process the message and then recognize the intent of the message and extract entities if they are present. If this is a simple conversational text then the Rasa server will utter a predefined response and will wait for the next message from the user or else the Rasa server will pass on the extracted entities to the Rasa action server that will call upon a certain action which will establish a connection with the database to either read/modify the database. Once all the processing is done, a feedback message will be uttered by the action server back to the user mentioning the status of the queried process.



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B. Design Implementation

- 1) Rasa: Rasa is an open-source Natural Language Processing tool for building chatbots. Using Rasa it was possible to build the chatbot and train it according to the custom dataset. To create a custom model we had to work mainly on four files in the Rasa file structure- 'nlu.yml', 'stories.yml', 'config.yml', and 'domain.yml'.
 - a) nlu.yml - This file stores all the example sentences for all the intent over which the model will be trained.
 - b) stories.yml - This file contains all the predefined conversation paths. A story is a representation of a conversation between the user and the chatbot.
 - c) domain.yml- In this file, all the intents, entities and slots are registered. It also stores some predefined responses(utterances).
 - d) config.yml - This file has all the details about the pipeline which is going to be used while training the model. There are many factors that can be customized to tune the model according to our choice and have varying results.
- 2) Rasa: Rasa action server hosts a file 'actions.py' which contains custom python scripts that can be used to connect to the database, external APIs or can be used to perform certain processing steps. Our project has a total of nineteen actions that are dedicated to perform operations like transactions, checking account balances, changing PINs, etc. Another file named 'otp.py' is present which has the function to send OTP to the user via mail using 'smtplib'.

Project Outputs

Our model makes use of the DIET classifier which stands for Dual Intent Entity Transformer Classifier. As the name suggests this model is able to recognize intents as well as extract the entities. A model trained over the above dataset achieved an accuracy of 98.4% and an F1 score of 0.862 with a loss of 1.24.



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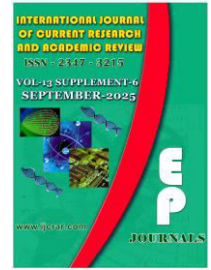


Table I Metrics with respect to intents

Intent	Precision	Recall	F1-score
amount_provided	1.0	0.0909	0.1669
stop_transfer	1.0	1.0	1.0
change_phoneno	1.0	1.0	1.0
greet	1.0	0.9230	0.9600
account_balance	1.0	1.0	1.0
inform_currency	1.0	1.0	1.0
credit_used	1.0	1.0	1.0
phoneno_provided	1.0	1.0	1.0
register_complaint	1.0	1.0	1.0
transfer_otp_provided	0.8461	1.0	0.9166
pin_change	1.0	1.0	1.0
complaint_provided	1.0	1.0	1.0
transfer_money	1.0	0.8636	0.9268
mini_statement	1.0	1.0	1.0
authinform	1.0	1.0	1.0
order_cheque_book	1.0	1.0	1.0
block_card	1.0	1.0	1.0
interest_rates	1.0	1.0	1.0
pin_provided	0.5416	1.0	0.7027
branch_locator	1.0	1.0	1.0
new_card	1.0	1.0	1.0

Table I provides the precision, recall and F1 score for all the domain-specific intents, and we can observe the accuracy is around 1.0 while precision and recall are close to each other. There



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are some intents that have low accuracy like pin_provided as it is ambiguous for the model to recognize PIN from various numerical entities like OTP, amount, phone number, etc.

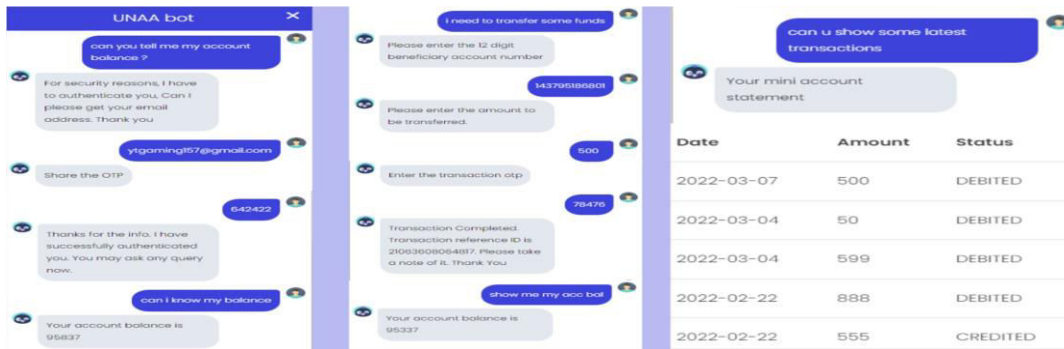


Fig. 2 Transaction Use Case

In Fig. 2 the user interface of the chatbot is shown where initially the user is asking about the account balance but here the user is not authenticated so the chatbot displays a message containing "For security reasons, I have to authenticate you, Can I please get your email address. Thank you". So the user will provide the email and an OTP (One Time Password) will be sent on the email provided. After successfully entering the OTP the user will get a message stating "Thanks for the info, I have successfully authenticated you. You may ask any query now." After that, the user asks about his/her account balance and the account balance is displayed.

Further, if the user wants to transfer some funds then the chatbot will ask the user to enter a 12 digit account number after that the amount which is to be transferred. For enhanced security purposes the user will have to enter a transaction OTP which is sent on his/her email. After successfully entering the transaction OTP the user will get a message where he/she is informed that the transaction is completed and a transaction reference id is provided.

If the user wants to know about his/her latest transactions a mini statement is provided as shown in Fig. 2.



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Future Scope

Performance can be enhanced by using various procedures of machine learning. Chatbots can be integrated with voice commands to enhance the user experience. More banking services can be simplified by the use of a powerful chatbot. The quality of chatbots can be improved in the future by research in the field of banking. Security of chatbots will have to be improved as the security will be improved, people will be willing to share their information with the chatbot and also data collection will get easier. In the banking domain, contextual assistants need to cover more Indian languages thereby increasing the usability of chatbots.

Conclusions

Implementation of this project would make the user experience of a customer on the website, more friendly and seamless. A chatbot can also act as an information-gathering tool that would help the organizations to inspect the needs of customers and then implement them.

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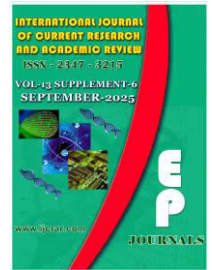


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