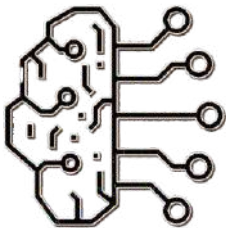


$$\pi = \frac{22}{7}$$

$$\pi = 3.14$$



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&

Computer Science

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Preface

The rapid evolution of science and technology in the 21st century has led to an unprecedented convergence of disciplines, particularly in the fields of mathematical modelling, computer science, and artificial intelligence. This edited volume, “Recent Trends in Mathematical Modelling, Computer Science and Artificial Intelligence,” is a scholarly attempt to capture the emerging paradigms, innovations, and interdisciplinary applications shaping the modern world.

Mathematical modelling has long served as the backbone of scientific inquiry, providing structured approaches to understanding complex systems. In recent years, its integration with artificial intelligence and computational techniques has significantly enhanced its scope and applicability. This book reflects that transformation by bringing together diverse contributions that explore both theoretical advancements and practical implementations.

The chapters in this volume cover a wide spectrum of topics. Foundational areas such as fuzzy game theory, number theory, calculus, linear algebra, and partial differential equations are explored in relation to artificial intelligence and machine learning. These contributions highlight how classical mathematical concepts continue to play a crucial role in designing intelligent systems and solving real-world problems.

At the same time, the book emphasizes contemporary technological developments, including agentic AI, multimodal intelligence, robotics, IoT-based smart systems, cloud and edge computing, and big data analytics. Several chapters address pressing global challenges, such as sustainable development goals (SDGs), smart agriculture, energy management, and economic forecasting, demonstrating the relevance of computational intelligence in policy and decision-making.

Cybersecurity and cryptography also form an important part of this volume, reflecting the growing need to secure digital infrastructures in an increasingly connected world. Contributions on ethical hacking, RSA cryptography, and cybersecurity awareness highlight both technical and societal dimensions of digital safety.

An equally important aspect of this book is its focus on human-centered challenges in the era of advanced technology. Topics such as emotion transfer between humans and AI, human intent detection, and mathematics anxiety in classrooms underscore the intersection of technology with psychology, education, and human behavior. These chapters remind us that technological progress must remain aligned with human values and inclusivity.

The diversity of contributions—from theoretical research to applied case studies—makes this volume a comprehensive resource for researchers, academicians, students, and practitioners. It not only showcases recent advancements but also encourages interdisciplinary thinking, which is essential for addressing complex global challenges.

We express our sincere gratitude to all the contributors for their valuable research work and intellectual efforts. Their dedication has made this volume rich in content and broad in perspective. We also thank the reviewers and supporting members who have contributed to maintaining the academic quality of this book.

We hope that this volume will serve as a useful reference and inspire further research in the dynamic fields of mathematical modelling, computer science, and artificial intelligence.

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Recent Trends in Mathematical Modelling, Computer Science and Artificial Intelligence

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Optimum Solution to Fuzzy Game Theory Problem Using Triangular Fuzzy Numbers and Trapezoidal Fuzzy Number

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Abstract

The objective of this article is to introduce a new ranking method based on the area of membership function of fuzzy numbers. This new ranking method is used to find the best approximate solution to the fuzzy game theory problem. "Game theory provides a mathematical process for selecting an optimal strategy. In Artificial Intelligence, Fuzzy Mathematics and fuzzy logic are used to process natural language and are widely used in decision making. In real-life, game theory, analysis is used in economic competition, economic conditions such as negotiation, auctions, voting theory etc. However, in real life situations, the information available for decision making to select an optimum strategy is imprecise. In this article, the crisp game theory problem is transformed into a fuzzy game theory problem by using triangular and trapezoidal fuzzy numbers. To order any two fuzzy numbers, a new and simple method invented which is based on the area of membership function. A computer program was written in Python which is given in this article to make calculations easier and simpler.

Keywords: Fuzzy, Triangular, Trapezoidal, Python, ranking, Saddle, Maximin, Minimax, Crisp, Strategy, Membership

1. Introduction:

Although the modern world sees significant changes in science and technology, part of the uncertainty cannot be avoided by any branch of science, engineering, medicine, and administration. It is well known that an important factor in the development of the modern concept of uncertainty was the publication of a seminar paper by Loft A. Zadeh in year 1965. In his article Zadeh transformed the probability theory and which is based on two value logic i.e. true or false. If 'A' is a fuzzy set and x is two valued logic, but it may be true to central degree to

which x is realistically a member of A . The degree of membership lies between the interval $[0,1]$. The crisp set defined in such a way that we can classify it into two groups such as members and non-members. (Ali MahmodiNejada, January 2011) invented new method of Ranking fuzzy numbers based on the areas on the left and the right sides of fuzzy number. (Mohamed A. H., Dec- 2020) introduced a New approach for ranking shadowed fuzzy numbers and Its application. (S. Salahshour S. Abbasbandy T., July 2011) used new techniques for ranking fuzzy numbers using fuzzy maximizing-minimizing points. (Savitha M T, 2017) make known to new methods for ranking of trapezoidal fuzzy nummbers. (Ganesan, 2018) used A new approach for the solution of fuzzy games using fuzzy numbers.

2. Some Basic Definition:

2.1 Triangular Fuzzy Number:

A triangular fuzzy number \tilde{A} or simply triangular number represented with three points as follows $\tilde{A} = (a_1, a_2, a_3)$ hold the following conditions.

- a. a_1 to a_2 membership function is increasing function
- b. a_2 to a_3 membership function is decreasing function.
- c. $a_1 \leq a_2 \leq a_3$

Its membership function is defined as follows

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1} & a_1 \leq x < a_2 \\ 1 & x = a_2 \\ \frac{(a_3-x)}{a_3-a_2} & a_2 < x \leq a_3 \end{cases}$$

2.2 Trapezoidal Fuzzy Number:

A Trapezoidal fuzzy number \tilde{A} or simply trapezoidal number represented with four points as follows $\tilde{A} = (a_1, a_2, a_3, a_4)$ hold the following conditions.

- a. a_1 to a_2 membership function is increasing function
- b. a_2 to a_3 membership function is 1.
- c. a_3 to a_4 membership function is decreasing function.
- d. $a_1 \leq a_2 \leq a_3 \leq a_4$

Its membership function is defined as follows

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1} & ; \text{if } a_1 \leq x < a_2 \\ 1 & ; \text{if } a_2 \leq x \leq a_3 \\ \frac{(a_4-x)}{a_4-a_3} & ; \text{if } a_3 < x \leq a_4 \end{cases}$$

2.3 Solution of all 2× 2 matrix game

Consider the general 2x2 game matrix $A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$ To solve this game we proceed as follows:

- a. Test for a saddle point
- b. If there is no saddle point, solve by finding equalizing strategies. The optimal mixed strategies for player $A = (p_1, p_2)$ and for player $B = (q_1, q_2)$

Where $p_1 = \frac{a_{22}-a_{21}}{(a_{11}+a_{22})-(a_{12}+a_{21})}$, $p_2 = 1 - p_1$ and

$$q_1 = \frac{a_{22} - a_{12}}{(a_{11} + a_{22}) - (a_{12} + a_{21})}, q_2 = 1 - q_1$$

Also Value of the game $V = \frac{a_{11}a_{22}-a_{21}a_{12}}{(a_{11}+a_{22})-(a_{12}+a_{21})}$

3. Ranking of Fuzzy Number

Let \tilde{A} be a fuzzy number with $\mu_{\tilde{A}}(x)$ is membership function which maps \mathbb{R} to $[0,1]$ and $Sup(\tilde{A}) = (a, b)$ is subset of \mathbb{R} . The measure of \tilde{A} is denoted by $R(\tilde{A})$ and defined as

$$R(\tilde{A}) = (a + b) \left[\frac{1}{b - a} * \text{Area of membership function } \mu_{\tilde{A}}(x) \text{ over } [a, b] \right]$$

$$i.e. R(\tilde{A}) = (a + b) \left[\frac{1}{b - a} \int_a^b \mu_{\tilde{A}}(x) dx \right]$$

3.1 Ranking of Triangular Fuzzy Number:

Let $\tilde{A} = (a_1, a_2, a_3)$ be a triangular fuzzy number with $\mu_{\tilde{A}}(x)$ is membership function and $Sup(\tilde{A}) = (a_1, a_3)$

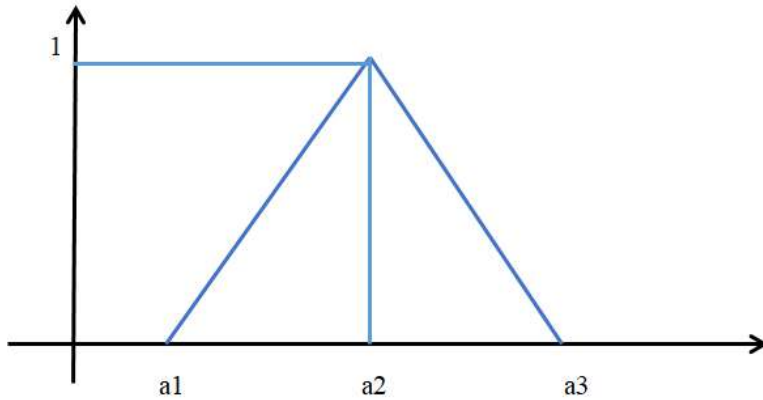


Fig 1: Triangular Fuzzy Number $[a_1, a_2, a_3]$

Area of membership function $\mu_{\tilde{A}}(x)$ over $[a_1, a_3]$

$$= \frac{1}{2} \times 1 \times (a_3 - a_1)$$

$$\therefore \text{Area of membership function } \mu_{\tilde{A}}(x) \text{ over } [a, b] = \frac{a_3 - a_1}{2}$$

$$\therefore R(\tilde{A}) = (a_1 + a_3) \left[\frac{1}{a_3 - a_1} \times \frac{a_3 - a_1}{2} \right]$$

$$\therefore R(\tilde{A}) = \frac{(a_1 + a_3)}{2}$$

3.2 Ranking of Trapezoidal Fuzzy Number

Let $\tilde{A} = (a_1, a_2, a_3, a_4)$ be a trapezoidal fuzzy number with $\mu_{\tilde{A}}(x)$ is membership function and $Sup(\tilde{A}) = (a_1, a_4)$

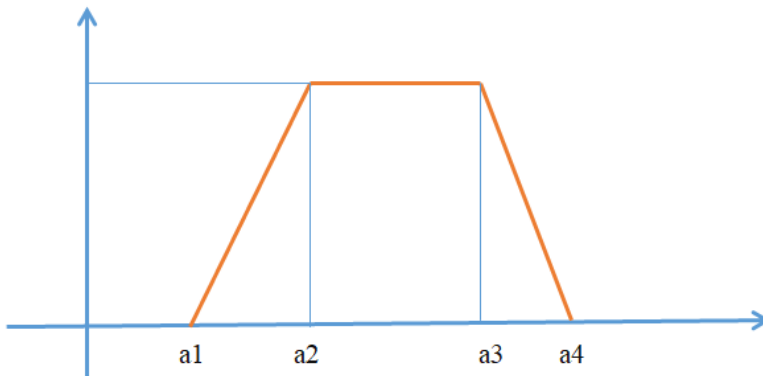


Fig 2: Trapezoidal Fuzzy Number

$$\begin{aligned} & \text{Area of membership function } \mu_{\tilde{A}}(x) \text{ over } [a_1, a_4] \\ &= \left[\frac{1}{2} \times 1 \times (a_2 - a_1) \right] + [(a_3 - a_2) \times 1] \\ &+ \left[\frac{1}{2} \times 1 \times (a_4 - a_3) \right] \end{aligned}$$

$$\therefore \text{Area of membership function } \mu_{\tilde{A}}(x) \text{ over } [a, b] = \frac{(a_3+a_4)-(a_1+a_2)}{2}$$

$$\therefore R(\tilde{A}) = (a_1 + a_4) \left[\frac{1}{a_4 - a_1} \times \frac{(a_3 + a_4) - (a_1 + a_2)}{2} \right]$$

$$\therefore R(\tilde{A}) = \frac{a_1 + a_4}{a_4 - a_1} \times \frac{(a_3 + a_4) - (a_1 + a_2)}{2}$$

$$\therefore R(\tilde{A}) = \frac{(a_1 + a_4)(a_3 + a_4 - a_1 - a_2)}{2(a_4 - a_1)}$$

4. Python Code for Ranking of Fuzzy Number:

```
n=int(input("Enter Your Choice for fuzzy number: 1:Triangular, 2: Trapezoidal="))
```

```
if(n==1):
```

```
    a1,a2,a3=[int(x) for x in input("Enter Your First Triagular Fuzzy number A=[a1,a2,a3]: ").split()]
```

```
    b1,b2,b3=[int(x) for x in input("Enter Your First Triagular Fuzzy number A=[b1,b2,b3]: ").split()]
```

```
    area1=(a1+a3)/2
```

```
    area2=(b1+b3)/2
```

```
    if(area1<=area2):
```

```
        print("A<<B")
```

```
    else:
```

```
        print("B<<A")
```

```
elif(n==2):
```

```
    a1,a2,a3,a4=[int(x) for x in input ("Enter Your First Triagular Fuzzy number A=[a1,a2,a3,a4]: ").split()]
```

```
    b1,b2,b3,b4=[int(x) for x in input ("Enter Your First Triagular Fuzzy number A=[b1,b2,b3,b4]: ").split()]
```

```
    area1=((a1+a4)*(a3+a4-a1-a2))/2
```

```
    area2=((b1+b4)*(b3+b4-b1-b2))/2
```

```
    if(area1<=area2):
```

```
        print("A<<B")
```

```
    else:
```

`print("B<<A")`

4.1 Some Output:

Enter Your Choice for fuzzy number: 1:Triangular, 2: Trapezoidal=1
 Enter Your First Triangular Fuzzy number A=[a1,a2,a3]: 5 6 7
 Enter Your First Triangular Fuzzy number A=[b1,b2,b3]: 1 2 3
B<<A

Enter Your Choice for fuzzy number: 1:Triangular, 2: Trapezoidal=2
 Enter Your First Triangular Fuzzy number A=[a1,a2,a3,a4]: 1 2 3 4
 Enter Your First Triangular Fuzzy number A=[b1,b2,b3,b4]: 3 4 5 6
A<<B

5. Examples:

1. Consider the following fuzzy game problem

$$\begin{array}{c}
 \text{Player B} \\
 \text{Player A} \quad \begin{bmatrix} (2,4,6) & (8,9,11) \\ (-2,0,3) & (-3,-1,1) \end{bmatrix}
 \end{array}$$

Solution:

Step 1:

Convert the given fuzzy problem into a crisp value problem

Fuzzy Number	Crisp value
$a_{11} = (2,4,6)$	$R(a_{11}) = 4$
$a_{12} = (8,9,11)$	$R(a_{12}) = 9.5$
$a_{21} = (-2,0,3)$	$R(a_{21}) = 0.5$
$a_{22} = (-3,-1,1)$	$R(a_{22}) = -1$

Step 2:

The pay-off matrix is

$$\begin{array}{c}
 \text{Player B} \\
 \text{Player A} \quad \begin{bmatrix} 4 & 9.5 \\ 0.5 & -1 \end{bmatrix}
 \end{array}$$

Minimum of 1st row = 4, Minimum of 2st row = -1, Maximum of 1st column = 4

Maximum of 2st column = 9.5

\therefore Maximin = 4 and Minimax = 4

It has saddle point and

\therefore Strategy for player A = A_1 and strategy for player B = B_1 .

Also Value of the game $V = 4$

5.1 Consider the following fuzzy game problem

Player B

$$\text{Player A} \begin{bmatrix} (2,4,5,6) & (4,8,9,11) \\ (-2,0,3,4) & (-3,-1,0,1) \end{bmatrix}$$

Step 1:

Convert the given fuzzy problem into a crisp value problem

Fuzzy Number	Crisp value
$a_{11} = (2,4,5,6)$	$R(a_{11}) = 5$
$a_{12} = (4,8,9,11)$	$R(a_{12}) = \frac{60}{7}$
$a_{21} = (-2,0,3,4)$	$R(a_{21}) = \frac{3}{2}$
$a_{22} = (-3,-1,0,1)$	$R(a_{22}) = -\frac{5}{4}$

Step 2:

The pay-off matrix is

Player B

$$\text{Player A} \begin{bmatrix} 5 & \frac{60}{7} \\ \frac{3}{2} & -\frac{5}{4} \end{bmatrix}$$

Minimum of 1st row = 5, Minimum of 2st row = $-\frac{5}{4}$, Maximum of 1st column = 5

Maximum of 2st column = $\frac{60}{7} \therefore$ Maximin = 5 and Minimax = 5

\therefore It has saddle point

\therefore Strategy for player A= A_1 , \therefore Strategy for player B = B_1 .

\therefore Value of the game $V = 5$

6. Conclusion:

In this paper, to develop a method for solving problems using triangular fuzzy numbers and trapezoidal fuzzy numbers by using ranking of triangular and trapezoid fuzzy numbers. This article proposes a simple and concrete method that ranks triangular and trapezoidal fuzzy numbers. The Python code is used to get the exact ordering of triangular fuzzy numbers. This method gives a correct ranking order for the problems for decision-making problems under uncertainty calculation, since it is easy to calculate and gives acceptable results. Through a numerical example, we can conclude that the value obtained from fuzzy game theory from this method is optimum. In the future we want to extend our work to solve the fuzzy game problem using the Pentagonal fuzzy number, Octagonal fuzzy number.

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Optimizing Global Resource Distribution: A Mathematical Approach to Achieving SDG

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Abstract

Achieving Sustainable Development Goal 12 (SDG 12)—ensuring sustainable consumption and production patterns—requires a fundamental shift in how global resources are managed and distributed. This paper examines the role of applied mathematics as a critical tool for reducing systemic waste and enhancing the efficiency of global supply chains. By framing the movement of commodities as a structured Transportation Problem, this research explores how rigorous mathematical modelling can minimize both economic costs and the environmental footprint of logistics. The study evaluates initial distribution strategies to establish optimized baseline routes. These are further refined using optimal solution techniques, to identify the most resource-efficient paths between production facilities and consumption destinations. By applying these algorithms, stakeholders can significantly reduce fuel consumption, prevent overproduction, and decrease transit-related waste. Ultimately, this research demonstrates that mathematical optimization is essential for operationalizing the principles of a circular economy, providing a quantitative pathway toward the targets set forth in SDG 12.

Keywords: Sustainable Development Goals, SDG 12, Transportation Problem, Optimization Techniques, Supply Chain Efficiency, Vogel’s Approximation Method (VAM)

1. Introduction

Mathematics serves as the essential language for operationalizing the United Nations 2030 Agenda. As the global community strives to achieve the 17 Sustainable Development Goals (SDGs), the transition from theoretical policy to measurable, real-world impact requires rigorous mathematical frameworks. This paper focuses on the

critical intersection of logistics and global sustainability, specifically addressing SDG2(Zero Hunger) and SDG12 (Responsible Consumption and Production).

At the core of these objectives lies the "Transportation Problem," a logistical challenge of moving essential commodities from production hubs to demand destinations with minimal economic and environmental cost. By employing structured optimization techniques—ranging from Initial Basic Feasible Solution methods like the Northwest Corner (NWCM), Least Cost (LCM), and Vogel’s Approximation Method (VAM) to optimal refinement techniques such as the Stepping Stone Method (SSM) and Modified Distribution Method (MDM)—we can maximize resource efficiency and reduce systemic waste. This study demonstrates how mathematical modeling transforms global supply chains into circular systems, reducing carbon emissions and ensuring equitable resource distribution. By applying these algorithms, we provide a quantitative, scalable pathway toward a more resilient, data-driven, and sustainable future, proving that mathematics is an indispensable tool for human development.

The analytical model can be conceptualized as a dual-layered system:

Layer	Strategic Focus	Mathematical Tools	Key SDG Target
Macro-Strategic	Predictive Resilience	Differential Equations, Simulations	Climate Change & Disaster Risk
Macro-Strategic	Policy Evaluation	Game Theory, Statistical Analysis	International Cooperation
Micro-Operational	Feasibility Mapping	NWCM, LCM, VAM	SDG 2 (Zero Hunger)
Micro-Operational	Optimal Refinement	SSM, MDM	SDG 12 (Responsible Consumption)

2. Real-Life Example: Food Supply Chain Optimization

Consider a scenario where a centralized food distribution hub must supply three distinct regions facing food insecurity. Without mathematical optimization, the hub might rely on heuristic-based shipping, which often ignores cost and carbon efficiency. By framing this as a Transportation Problem (TP), the system applies Vogel’s Approximation Method (VAM) to generate an initial, efficient route, followed by the Modified Distribution Method (MDM) to iteratively eliminate inefficiencies. This process directly minimizes the total cost function which serves as a proxy for both economic expenditure and the carbon footprint of transport.

3. The Constraint of Ethical Transparency

The research emphasizes that mathematical models are not value-neutral. The effectiveness of the "Sustainable Impact" model depends on the integration of ethics:

$$\text{Sustainable Impact} = (\text{Mathematical Optimization}) \times (\text{Ethical Transparency}) \times (\text{Interdisciplinary Cooperation})$$

The analytical findings indicate that even technically optimal models can fail if they ignore algorithmic bias or local context. Therefore, the "Macro" approach (using simulations to predict environmental shifts) and the "Micro" approach (optimizing logistics) must be governed by transparent data practices.

In conclusion, mathematics acts as the "universal language" of the 2030 Agenda. By transforming abstract goals into quantifiable optimization problems, researchers provide the analytical architecture for a resilient future. Success relies on balancing the rigor of linear programming with the inclusivity of ethical modeling, ensuring that the advancement of the SDGs remains both technically sound and human-centric

4. Methodology:

The proposed research framework adopts a dual-layered mathematical approach to operationalize the United Nations Sustainable Development Goals (SDGs) by integrating macro-strategic modeling with micro-operational optimization. At the strategic level, the framework utilizes advanced computational simulations and differential equations to forecast environmental patterns and climate change shifts, while employing game theory to evaluate international cooperation on carbon reduction. This predictive foundation allows for more robust global policy design and disaster risk assessment. To translate these broad goals into field-level implementation, the framework incorporates linear programming to resolve logistical inefficiencies, specifically addressing SDG2 (Zero Hunger) and SDG12 (Responsible Consumption). This is achieved by treating resource distribution as a Transportation Problem (TP), first establishing feasibility through methods such as the Northwest Corner Method (NWCN) or Vogel's Approximation Method (VAM), and subsequently refining these routes using the Modified Distribution Method (MDM) to minimize transportation costs and resource waste. This technical workflow is further supported by an ethical and educational framework that prioritizes data transparency and fosters mathematical literacy through project-based learning, effectively bridging the gap between abstract mathematical theory and sustainable global development

5. Conclusion

Mathematics serves as an indispensable and transformative tool for addressing the interconnected challenges inherent in the UN's Sustainable Development Goals (SDGs). By providing the analytical architecture for data modeling and system optimization, mathematics bridges the gap between theoretical policy and practical, real-world implementation. The research confirms that achieving sustainability is fundamentally an optimization challenge; success depends on both the macro-level ethical application of data and the micro-level use of rigorous mathematical algorithms. By establishing efficient distribution routes for critical resources and improving environmental forecasting, mathematical modeling reduces systemic waste and fosters equitable access. Ultimately, humanity can advance toward a resilient, data-driven future only by responsibly leveraging mathematical power, fostering international cooperation, and continuously adapting these technical techniques to address the evolving and complex global concerns of our time.

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AI for Detecting Human Intent Before Action Using Multimodal Behavioral Signals

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Abstract

Predicting human intent before an action occurs is an emerging challenge in artificial intelligence and human–computer interaction. Traditional AI systems react only after actions are completed, which limits their effectiveness in time-critical environments such as autonomous driving, surveillance, healthcare, and robotics. This research proposes a multimodal AI framework that analyzes behavioral signals—such as eye movement, body posture, facial expressions, and voice tone—to predict human intentions before the action is executed. The proposed system integrates computer vision, speech analysis, and deep learning models to detect patterns associated with upcoming actions. Experimental evaluation using multimodal datasets demonstrates that early intention prediction can significantly improve response time and decision accuracy in intelligent systems. The study highlights both the potential applications and ethical implications of predictive AI technologies.

1. Introduction

Artificial intelligence has achieved significant progress in recognizing and classifying human actions. However, most existing systems focus on post-action recognition, meaning the AI identifies actions only after they have occurred. In many real-world scenarios, such as autonomous vehicles or assistive robotics, waiting until the action happens may be too late.

Humans often show pre-action signals, including micro-gestures, gaze direction, muscle movement, and subtle voice changes. These signals can indicate a person's intention before the action occurs. If AI systems can interpret these signals effectively, they could anticipate human behavior and respond proactively.

The purpose of this research is to design an AI model capable of predicting human intent before the action occurs by analyzing multimodal behavioral data. This

approach combines computer vision, natural language processing, and deep learning to create a predictive system that understands human intention.

2. Background and Related Work

Previous research in human behavior analysis has primarily focused on action recognition and gesture detection. Deep learning models such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs) have shown strong performance in recognizing activities from video data.

Recent studies have started exploring intent prediction, particularly in fields such as autonomous driving and human-robot interaction. For example, gaze tracking systems have been used to predict where a person intends to move, while motion analysis models attempt to predict the next step in human movement.

However, most existing models rely on a single data modality, such as visual data alone. Human intention is complex and often expressed through multiple signals simultaneously. Therefore, combining different behavioral cues may significantly improve prediction accuracy.

3. Research Objectives

The main objectives of this research are:

1. To design an AI system that predicts human intent before an action occurs.
2. To analyze behavioural signals such as gaze direction, facial expressions, body movement, and voice patterns.
3. To develop a multimodal deep learning model that integrates multiple data sources.
4. To evaluate the effectiveness of early intent prediction in real-time environments.

4. Proposed Methodology

4.1 Data Collection

The system will use multimodal datasets consisting of:

- Video recordings of human actions
- Eye-tracking data
- Speech recordings
- Motion capture or skeleton tracking data

4.2 Feature Extraction

Different AI techniques will extract meaningful features from each modality.

4.3 Multimodal AI Model

A hybrid deep learning architecture will combine the extracted features:

4.4 Training and Evaluation

The model will be trained using supervised learning techniques.

5. Potential Applications

Autonomous Vehicles

AI could predict pedestrian intent to cross the road before they step onto the street.

Human–Robot Collaboration

Robots could anticipate human actions in factories and assist more efficiently.

Security and Surveillance

Suspicious behaviors could be detected before harmful actions occur.

Healthcare Monitoring

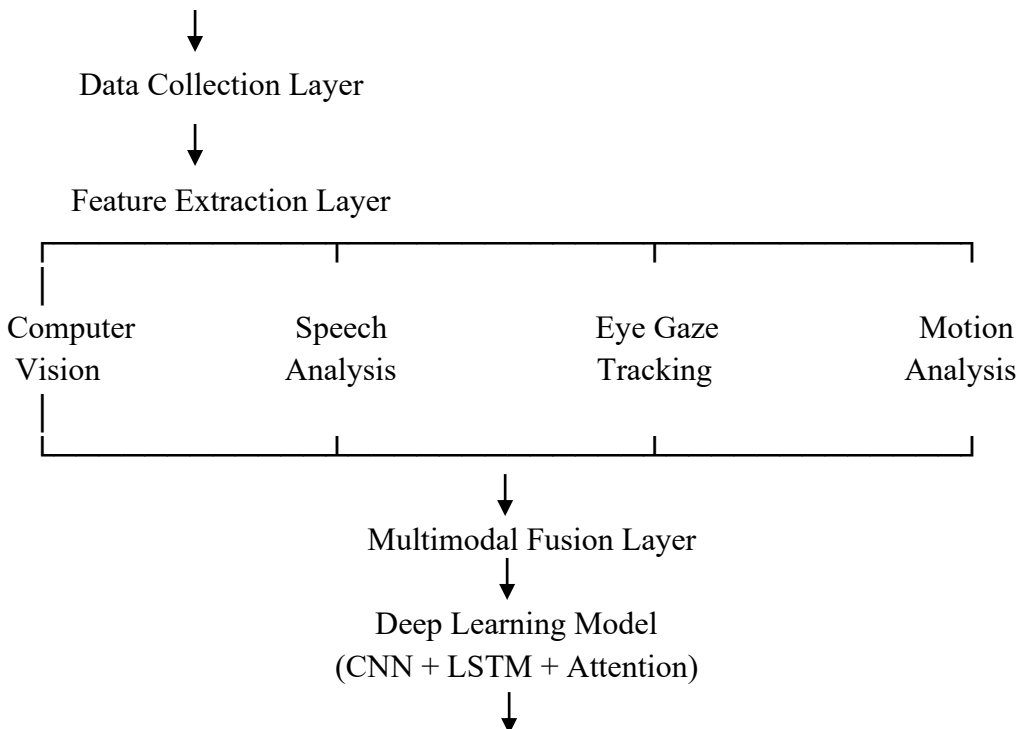
Systems could detect patient intentions, such as attempting to stand or move, reducing fall risks.

1. Overall System Architecture Diagram

This diagram shows the complete workflow of the proposed AI system.

Human Behaviour Signals

(Video, Voice, Eye Movement, Gesture)

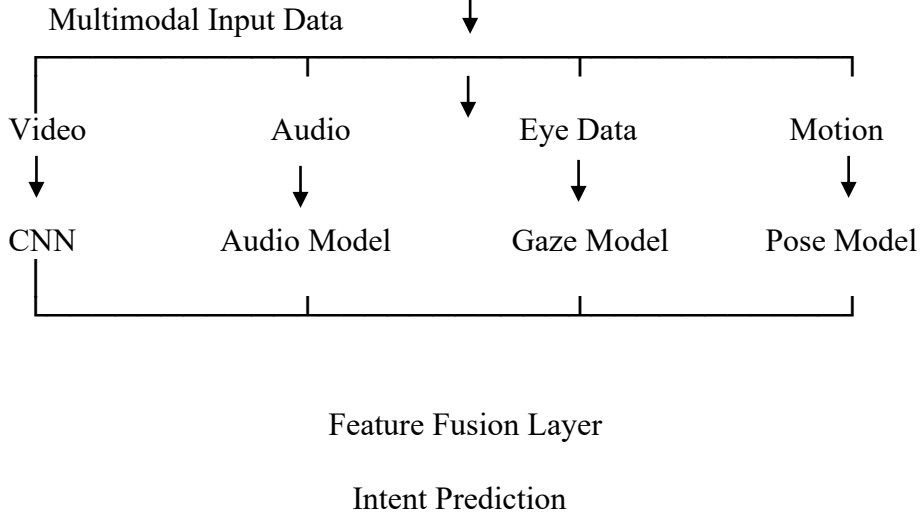


Intent Prediction Output
(Action predicted before event)

Purpose:

Shows the **entire AI pipeline** from data input to intent prediction.

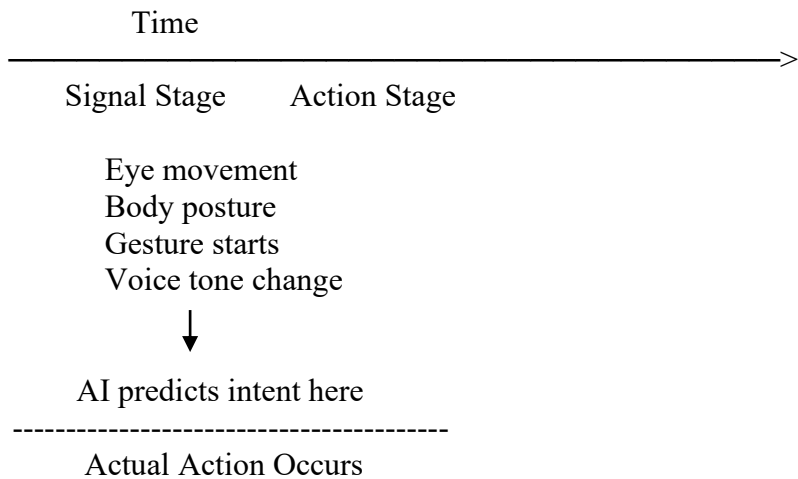
2. Multimodal Data Processing Diagram



Purpose:

Shows how **multiple data types are combined** to improve prediction accuracy.

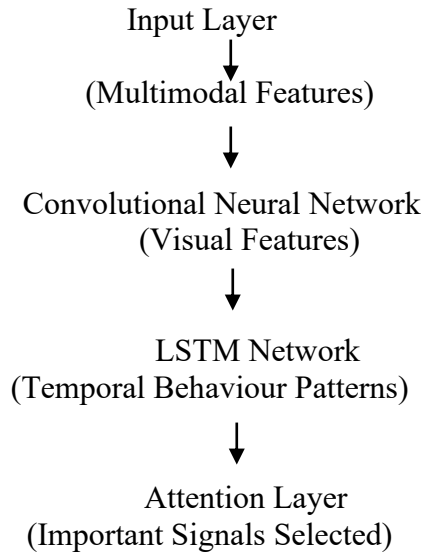
3. Intent Prediction Timeline Diagram



Purpose:

Illustrates that the **AI predicts intent before the action actually happens.**

4. Deep Learning Model Structure



6. Conclusion

Predicting human intent before an action occurs represents a significant advancement in artificial intelligence. By integrating multiple behavioural signals through multimodal deep learning models, AI systems can anticipate human actions and respond proactively. This research proposes a framework that combines visual, speech, and motion data to improve early intent detection. Future work may focus on improving real-time performance, expanding datasets, and addressing ethical concerns associated with predictive AI technologies.

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Emotion Transfer Between Humans and AI: A Multimodal Artificial Intelligence Approach

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Abstract

Human emotions play a critical role in communication, decision-making, and social interaction. As artificial intelligence systems increasingly interact with humans through conversational agents, robots, and virtual assistants, the ability to understand and respond to emotions becomes essential. This research explores the concept of emotion transfer between humans and AI, where artificial intelligence not only detects human emotional states but also adapts its responses to influence or regulate those emotions. The proposed framework integrates multimodal emotion recognition using facial expressions, speech tone, and textual sentiment analysis. A deep learning architecture processes these signals to identify emotional states and generate emotionally adaptive responses. The study highlights potential applications in mental health support, education, and human–computer interaction while addressing ethical concerns related to emotional manipulation and privacy.

1. Introduction

Human communication is strongly influenced by emotions. Facial expressions, voice tone, and word choices often reveal emotional states such as happiness, sadness, frustration, or excitement. Traditional AI systems focus mainly on logical responses and task completion without considering emotional context.

Recent developments in affective computing have enabled machines to detect emotional signals. However, most systems only recognize emotions rather than interact with them dynamically. Emotion transfer refers to the process where AI systems understand human emotions and respond in ways that influence or stabilize those emotions.

2. Background and Related Work

The study of emotion-aware artificial intelligence originates from the field of affective

computing, which investigates how machines can detect and interpret human emotions.

Existing approaches commonly use:

- Facial expression recognition using computer vision
- Speech emotion detection through acoustic analysis
- Text-based sentiment analysis

3. Research Objectives

The primary objectives of this research are:

1. To design an AI framework capable of recognizing human emotions using multimodal signals.
2. To develop algorithms that generate emotionally adaptive responses.
3. To investigate whether AI responses can influence or regulate human emotional states.
4. To evaluate the effectiveness of emotion-aware AI in interactive environments.

4. Proposed Methodology

4.1 Data Collection

The system collects emotional signals from multiple sources:

- Facial expressions captured through video cameras
- Voice recordings during conversations
- Text-based communication from chat interfaces
- Physiological signals (optional) such as heart rate or skin conductance
- These signals provide comprehensive information about the user’s emotional state.

4.2 Feature Extraction

Each input modality undergoes feature extraction using specialized AI models. Examples include:

- Facial landmark detection for expression analysis
- Acoustic features such as pitch, tone, and speech intensity
- Natural language processing for sentiment and emotional tone.
- The extracted features represent emotional indicators.

4.3 Multimodal Emotion Recognition Model

The system integrates multiple deep learning components:

- Convolution Neural Networks (CNN) for facial image processing

- Recurrent Neural Networks (RNN) or Long Short-Term Memory (LSTM) models for speech and temporal data
- Transformer-based models for text emotion analysis

A fusion layer combines outputs from each model to determine the final emotional classification.

4.4 Emotion Response Generation

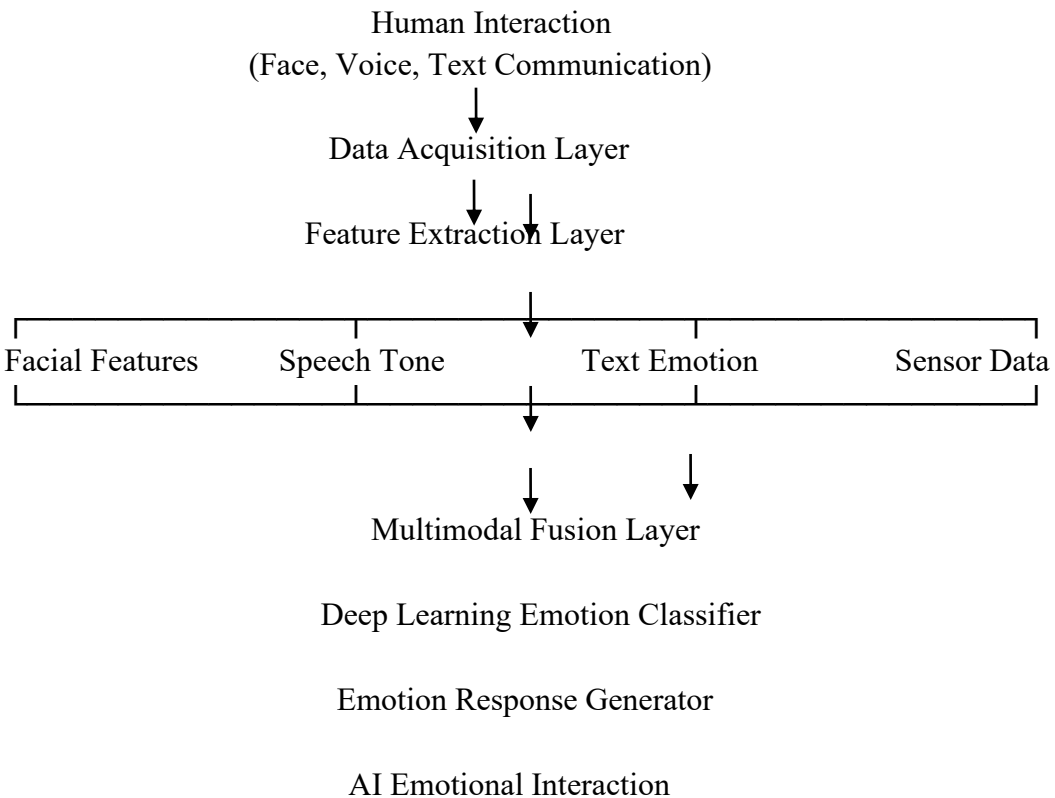
After detecting the emotional state, the AI system generates responses designed to interact emotionally with the user.

Examples:

- Encouraging messages when frustration is detected
- Calm responses when anger is identified
- Positive reinforcement when happiness is detected

The response module uses natural language generation models and emotional response strategies.

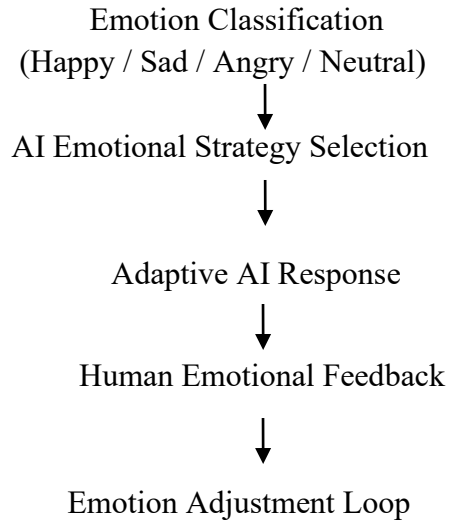
5. System Architecture Diagram



6. Emotion Interaction Workflow Diagram

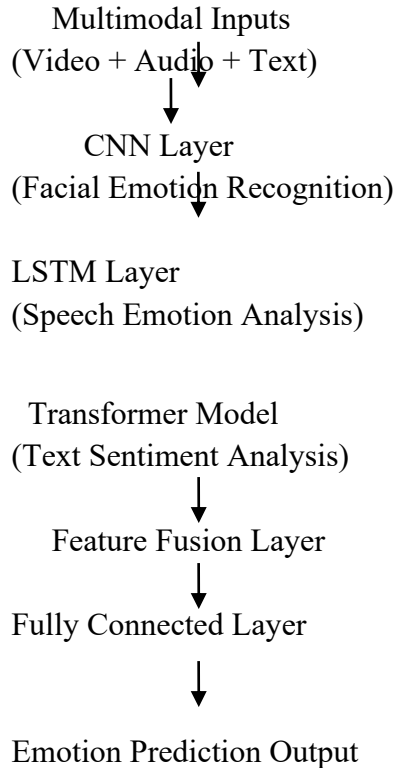
Human Emotion Detected





This diagram illustrates how AI continuously adapts its responses based on emotional feedback.

7. Deep Learning Model Structure



8. Applications

Mental Health Support

Emotion-aware chat bots may help detect stress or sadness and provide supportive conversation.

Intelligent Tutoring Systems

Educational AI can adapt teaching strategies based on student emotions.

Customer Service Automation

Emotion-sensitive assistants can respond empathetically to frustrated customers.

9. Conclusion

Emotion transfer between humans and artificial intelligence represents a significant advancement in human–computer interaction. By combining multimodal emotion recognition with adaptive response generation, AI systems can engage in emotionally meaningful interactions with users. This research proposes a framework that integrates visual, speech, and textual analysis to detect emotions and generate context-aware responses. Future research may explore real-time emotion adaptation, cross-cultural emotional interpretation, and stronger privacy safeguards.

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AI-Based Smart Agriculture Using IoT Sensors

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Abstract

Agriculture is undergoing a technological transformation driven by Artificial Intelligence (AI) and the Internet of Things (IoT). This paper presents a smart agriculture system that integrates IoT sensors with AI algorithms to optimize crop productivity, reduce resource wastage, and support sustainable farming. The proposed system collects real-time data such as soil moisture, temperature, humidity, and crop health using IoT devices. AI models analyze this data to provide predictive insights and automated decision-making. The results demonstrate improved irrigation efficiency, reduced operational costs, and enhanced crop yield. This study highlights the potential of AI-driven IoT systems in modern agriculture and discusses implementation challenges and future opportunities. In recent years, the integration of Artificial Intelligence (AI) and the Internet of Things (IoT) has emerged as a transformative solution in the agricultural sector. IoT enables the deployment of smart sensors in agricultural fields to continuously monitor critical parameters such as soil moisture, temperature, humidity, light intensity, and nutrient levels.

Artificial Intelligence complements IoT by analyzing the collected data and generating meaningful insights. AI algorithms can identify patterns, predict crop growth, detect diseases at early stages, and recommend optimal irrigation schedules. This combination allows farmers to make data-driven decisions rather than relying solely on traditional methods.

The concept of smart agriculture, also known as precision farming, focuses on optimizing inputs and improving crop yield through automation and intelligent monitoring systems. By using AI-based IoT solutions, farmers can reduce wastage, minimize environmental impact, and increase efficiency. Additionally, automated systems can help address labor shortages and reduce human errors in farming operations.

Despite its advantages, the adoption of AI-based smart agriculture faces challenges such as high initial costs, lack of technical knowledge, and limited connectivity in rural areas. Nevertheless, continuous advancements in technology and increasing awareness among farmers are expected to drive the widespread adoption of these systems.

This paper aims to explore the design and implementation of an AI-based smart agriculture system using IoT sensors, highlighting its benefits, challenges, and future potential in modern farming.

Keywords- Smart Agriculture, Artificial Intelligence, Internet of Things, Precision Farming, Crop Monitoring, Automation

1. Introduction

Agriculture remains a critical sector for global food security, yet traditional farming methods often suffer from inefficiencies, unpredictable weather conditions, and resource mismanagement. With increasing population demands, there is a need for intelligent systems that can enhance productivity while minimizing environmental impact.

Smart agriculture combines IoT and AI technologies to monitor and manage farming activities. IoT devices gather environmental and soil-related data, while AI techniques process this information to generate actionable insights. This integration enables precision farming, where decisions are based on real-time and historical data rather than assumptions.

2. Literature Review

Recent studies have explored the use of IoT sensors for monitoring agricultural fields. Systems using soil moisture sensors and weather stations have shown significant water savings. AI techniques such as machine learning and deep learning have been applied for crop disease detection, yield prediction, and irrigation planning.

However, many existing systems operate independently, focusing either on IoT-based monitoring or AI-based analysis. Limited research has been conducted on fully integrated systems that combine real-time sensing with intelligent decision-making.

3. System Architecture

3.1 Overview

The proposed system consists of three main components:

1. IoT Sensor Layer

2. Data Processing Layer
3. Application Layer

3.2 IoT Sensor Layer

This layer includes sensors deployed in the agricultural field:

- Soil moisture sensor
- Temperature and humidity sensor
- pH sensor
- Light intensity sensor

These sensors continuously collect environmental data and transmit it to a central server using wireless communication technologies such as Wi-Fi, LoRa, or GSM.

3.3 Data Processing Layer

- Machine learning models predict irrigation needs
- Classification models detect crop diseases
- Time-series analysis forecasts weather patterns

3.4 Application Layer

Farmers interact with the system through a mobile or web application that provides:

- Real-time monitoring dashboards
- Alerts and recommendations
- Automated irrigation control

4. Methodology

4.1 Data Collection

Sensors are deployed across the field to capture continuous data. The data is stored in a cloud database for further processing.

4.2 Data Preprocessing

Collected data is cleaned and normalized to remove noise and inconsistencies.

4.3 Model Development

Machine learning algorithms such as:

- Decision Trees
- Random Forest
- Neural Networks

are trained using historical and real-time data to predict optimal farming actions.

4.4 Automation

Based on AI predictions, irrigation systems are automatically activated or deactivated, ensuring efficient water usage.

5. Results and Discussion

The implementation of the proposed system shows:

- Reduction in water usage by up to 30–40%
- Increase in crop yield due to precise irrigation
- Early detection of crop diseases

The system also reduces manual labor and enables farmers to make informed decisions. However, challenges such as high initial cost, connectivity issues, and lack of technical awareness among farmers must be addressed.

6. Advantages

- Efficient resource utilization
- Real-time monitoring
- Increased productivity
- Reduced human intervention
- Sustainable farming practices

7. Limitations

- High setup cost
- Dependence on internet connectivity
- Requirement of technical knowledge
- Sensor maintenance issues

8. Future Scope

Future developments can include:

- Integration with satellite imaging
- Use of advanced deep learning models
- Blockchain for supply chain transparency
- Edge computing for faster processing

9. Conclusion

AI-based smart agriculture using IoT sensors represents a promising solution to modern farming challenges. By combining real-time data collection with intelligent analysis, farmers can optimize resource usage and improve crop yield. Although there are challenges in adoption, advancements in technology and cost reduction are expected to make these systems more accessible. This approach can play a vital role in ensuring food security and sustainable agricultural practices in

the future.

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Era of the Upcoming Generation: Agentic AI (Application-Oriented) Innovation in Science and Technology

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Abstract

The rapid advancement of Artificial Intelligence is transforming scientific research and technological development worldwide. A new paradigm known as Agentic Artificial Intelligence focuses on application-oriented intelligent systems that can independently analyze problems, make decisions, and execute tasks. These AI agents move beyond traditional tools by performing multi-step operations with minimal human intervention. This paper explores the emerging role of agentic AI in science and technology, highlighting its applications in research, healthcare, robotics, and industry. It also discusses the benefits, challenges, and future impact of agentic AI on innovation for the upcoming generation.

Keywords: Agentic AI, Artificial Intelligence, Autonomous Systems, Innovation, Scientific Research

1. Introduction

The world is entering a new technological era where intelligent machines assist humans in solving complex scientific and technological challenges. Artificial intelligence has evolved from simple rule-based programs to highly advanced systems capable of learning from large datasets and making intelligent decisions. The latest development in this field is agentic AI, which emphasizes autonomous behavior and goal-oriented actions. Unlike traditional AI systems that respond only to user instructions, agentic AI systems can analyze information, create plans, and perform tasks independently to achieve defined objectives. These capabilities make them valuable tools for accelerating innovation in science and technology.

2. Concept of Agentic Artificial Intelligence

Agentic AI refers to systems that can perceive their environment, reason about possible solutions, and take actions to accomplish specific goals. Such systems act as autonomous software agents capable of interacting with digital environments and external tools.

Agentic AI differs from conventional AI in several ways:

- It performs multi-step decision making rather than single responses.
- It can plan and execute tasks autonomously.
- It can adapt to changing environments and learn continuously.
- It can interact with other systems, tools, and databases.

These characteristics enable agentic AI systems to function as intelligent assistants for researchers, engineers, and organizations.

3. Applications of Agentic AI in Science and Technology

3.1 Scientific Research

Agentic AI can assist researchers by analyzing large datasets, reviewing scientific literature, and designing experiments. Autonomous AI agents may generate hypotheses, conduct simulations, and refine research models, helping scientists accelerate the discovery process.

3.2 Healthcare and Biomedical Research

In healthcare, agentic AI can support diagnosis, treatment planning, and drug discovery by analyzing medical images, genomic data, and patient records. AI agents can also assist doctors in clinical decision-making and patient monitoring.

3.3 Robotics and Automation

Agentic AI enables robots to perform complex tasks in manufacturing, laboratories, and service industries. Intelligent robots can adapt to their environment, collaborate with humans, and improve productivity.

3.4 Smart Industries and Digital Infrastructure

Industries use agentic AI systems for supply chain optimization, predictive maintenance, and automated decision-making. These technologies help organizations improve efficiency and reduce operational costs.

4. Benefits of Agentic AI

Agentic AI offers several advantages for scientific and technological innovation:

- Faster analysis of large datasets
- Improved efficiency in research and development
- Autonomous problem solving
- Reduced human workload

- Enhanced accuracy in decision-making

These benefits demonstrate the potential of agentic AI to transform modern research environments and technological systems.

5. Challenges and Ethical Considerations

Despite its benefits, the adoption of agentic AI raises several challenges:

- Data privacy and cybersecurity risks
- Ethical concerns regarding autonomous decision-making
- High computational and infrastructure requirements
- Lack of transparency in AI algorithms

Researchers and policymakers must establish guidelines to ensure responsible development and deployment of agentic AI systems.

6. Future Prospects

The future of agentic AI will involve integration with emerging technologies such as robotics, cloud computing, and advanced data analytics. Autonomous AI systems may soon assist scientists in designing experiments, analyzing research findings, and solving global challenges such as climate change, healthcare, and sustainable energy.

As these technologies evolve, agentic AI will play a crucial role in shaping the next generation of scientific and technological innovation.

7. Conclusion

Agentic artificial intelligence represents a major advancement in the evolution of intelligent technologies. By enabling machines to act autonomously and execute complex tasks, agentic AI can significantly accelerate innovation in science and technology. With responsible governance and ethical development, agentic AI will become an essential tool for researchers, industries, and future generations.

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Information and Communication Technology: Cyber Security for Naive Users

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Abstract

Cybersecurity is the practice of protecting systems, networks, and data from digital attacks, often described through the CIA Triad—ensuring information remains Confidential, its Integrity is maintained, and it stays Available to authorized users. For "naive" or non-expert users, security can be abstracted into layers and simple behavioral habits to manage risk without needing deep technical knowledge.

Keywords: Agentic AI, Artificial Intelligence, Autonomous Systems, Innovation, Scientific Research

1. Introduction

The core purpose of cyber security for naive or non-technical users is to act as a protective shield for their digital lives, safeguarding personal information, devices, and online accounts from theft, damage, or misuse. As technology becomes central to daily life, these measures prevent cybercriminals from exploiting human error or inexperience to steal money, personal data, or identities.

2. Methods

A. Password Hygiene

- 1. Use Strong, Unique Passwords:** Create long, complex passwords that are hard to guess. Avoid using the same password across multiple websites.
- 2. Use a Password Manager:** Instead of remembering dozens of passwords or writing them on paper, use a password management tool to generate and store them securely.
- 3. Never Share Login Details:** Keep your usernames and passwords private.

3. Authentication and Access

- 1. Enable Multi-Factor Authentication (MFA):** Use 2FA or MFA whenever possible. This adds a second layer of security (like a code sent to your phone), reducing unauthorized access by up to 99.9%.
- 2. Lock Your Screen:** Lock your computer or phone screen immediately when you walk away from it.

3. Safe Browsing and Communication

- 1. Spot Suspicious Emails (Phishing):** Be wary of emails that demand urgent action, ask for payment, or have poor grammar. Do not click on links or open attachments from unknown sources.
- 2. Use Secure Wi-Fi:** Avoid using public Wi-Fi for sensitive activities (banking, shopping). If you must, use a Virtual Private Network (VPN) to encrypt your data.
- 3. Avoid Unfamiliar Sites:** Steer clear of unknown websites and useless downloads.

4. Device and Software Protection

- 1. Keep Software Updated:** Regularly update your operating system (Windows, iOS, Android) and applications to patch security holes.
- 2. Install Anti-Virus/Malware Software:** Use security software to detect and remove malicious code, and keep it up-to-date.
- 3. Use Official App Stores:** Only download applications from trusted, official platforms like Google Play Store or Apple App Store.

5. Data Management

- 1. Back Up Data Regularly:** Regularly back up your data to an external hard drive or a secure cloud service. Ensure your backup is not always connected to your live computer.
- 2. Dispose of Devices Safely:** Before disposing of old phones or computers, wipe the data completely using specialized software.

6. General Awareness

- 1. Be Aware of Surroundings:** In shared spaces, be aware that others may see your screen. Use a privacy screen if necessary.
- 2. Use Fake Information:** For non-critical accounts, consider using a fake birthday to prevent identity theft.

7. Key Findings

Key findings in cyber security for naive or non-technical users highlight that human behaviour is the most significant vulnerability, with over 80% of security breaches involving a human element. Naive users are often targets of social engineering, such as phishing, and frequently exhibit risky behaviors like password reuse and ignoring software updates.

1. Human Behaviors as Weakest Links

- 1. Complacency and Ignorance:** Users often ignore or bypass security measures because they perceive them as obstacles, not protections.
- 2. Trusting Nature:** Many users, particularly older adults, are overly trusting of online strangers and sources.
- 3. Risky Habits:** Common errors include writing passwords on sticky notes, using the same password across multiple sites, and delaying software updates.
- 4. Low Perceived Risk:** Nearly half of users (48%) do not believe they have ever been victims of a cyber-attack, despite evidence to the contrary.

2. Primary Threats to Naive Users

- 1. Phishing & Social Engineering:** Phishers trick users into revealing confidential information (credentials, bank details) by pretending to be trusted entities.
- 2. Password Weakness:** Attackers use "dictionary attacks" to guess simple passwords like "123456" or "password".
- 3. Insecure Wi-Fi:** Using public or unsecured Wi-Fi for sensitive tasks leaves data vulnerable to interception.
- 4. Malware & Key loggers:** Malicious software can be downloaded unintentionally, running in the background to steal credentials (key loggers) or encrypt files for ransom.

3. Essential Security Measures (Simple Steps)

- 1. Use Strong, Unique Passwords:** Use different, complex passwords for every account to prevent a single breach from compromising all your data.
- 2. Enable Multi-Factor Authentication (MFA):** This provides an extra layer of security (e.g., a code sent to your phone) even if your password is stolen.
- 3. Update Software Immediately:** Delays in updating operating systems and apps leave security vulnerabilities open.
- 4. Use Security Software:** Employ anti-virus, anti-malware, and anti-spyware programs to detect malicious code.

4. Psychological & Behavioural Factors

1. Individual Differences: Personality traits like impulsivity, high risk-taking behaviour and procrastination contribute to poor compliance with security policies.

2. Education Gap: There is a need for better training that focuses on the *why* behind security, rather than just the rules.

3. Key Takeaway: For non-technical users, security is not about being an expert, but about adopting a "never trust, always verify" mindset and implementing fundamental, automated security habits.

8. Core Vulnerabilities of Naive Users

1. Social Engineering Exploitation: Naive users are easily manipulated by "weapons of influence" (authority, urgency, or artificial rapport) to divulge sensitive information.

2. Phishing susceptibility: A lack of awareness means these users are more likely to click on malicious links in emails or messages, which accounts for 94% of malware delivery.

3. Password Mismanagement: Using simple, memorable passwords or reusing the same password across multiple platforms allows hackers to easily compromise all their accounts once one is breached.

4. Passive Security Approach: Naive users often delay or skip critical security updates, leaving their devices vulnerable to known exploits.

9. Conclusion

For naive or non-technical users, cyber security should be viewed not as a complex technical hurdle, but as a set of simple, essential safety habits similar to locking a house door or wearing a seatbelt. The primary takeaway is that while no system is 100% secure, adopting a few proactive, "common-sense" practices significantly reduces the risk of falling victim to cybercrime.

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Robotics and Automation

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Abstract

Robotics and automation represent a transformative technological revolution reshaping industries, economies, and everyday life. Robotics involves the design, development, and application of intelligent machines capable of performing tasks autonomously or semi-autonomously. Automation refers to the use of control systems, artificial intelligence, and machinery to perform processes with minimal human intervention. This paper explores the evolution, technologies, applications, benefits, challenges, and future prospects of robotics and automation. The study highlights how automation improves productivity, safety, accuracy, and cost efficiency while also raising concerns about employment, ethical issues, and security. The paper concludes that robotics and automation will continue to play a vital role in shaping smart industries and sustainable development.

Keywords: Robotics, Automation, Artificial Intelligence, Industrial Robots, Smart Manufacturing, Industry 4.0

1. Introduction

Robotics and automation have become integral components of modern technological advancement. Robotics combines mechanical engineering, electronics, computer science, and artificial intelligence to create machines capable of performing tasks traditionally carried out by humans. Automation enhances these capabilities by enabling systems to operate independently using programmed instructions and intelligent decision-making.

With the rise of Industry 4.0, robotics and automation are driving efficiency, precision, and innovation across sectors including manufacturing, healthcare, agriculture, logistics, and services.

2. Evolution of Robotics and Automation

The development of robotics has evolved through several stages:

- **1950s–1960s:** Introduction of industrial robots in manufacturing.
- **1970s–1980s:** Programmable automation and robotic arms used in assembly lines.
- **1990s:** Integration of sensors and computer vision.
- **2000s:** AI-powered robots and autonomous systems.
- **Present:** Collaborative robots (cobots), smart factories, and autonomous vehicles.

One of the earliest industrial robots, Unimate, revolutionized factory automation.

3. Key Technologies in Robotics and Automation

3.1 Artificial Intelligence (AI)

AI enables robots to learn, adapt, and make decisions using machine learning and deep learning algorithms.

3.2 Sensors and Computer Vision

Sensors help robots detect objects, temperature, pressure, and motion. Computer vision allows robots to interpret visual data.

3.3 Internet of Things (IoT)

IoT connects machines and devices, enabling real-time monitoring, data exchange, and predictive maintenance.

3.4 Control Systems

Advanced control algorithms ensure precision, stability, and safety in robotic operations.

3.5 Human-Robot Interaction (HRI)

Collaborative robots work alongside humans safely and efficiently.

4. Applications of Robotics and Automation

4.1 Manufacturing

Robots perform welding, painting, assembly, packaging, and quality inspection with high precision.

4.2 Healthcare

Robotic systems assist in surgery, rehabilitation, and patient care. Systems like da Vinci Surgical System enable minimally invasive procedures.

4.3 Agriculture

Automation supports precision farming, crop monitoring, and harvesting.

4.4 Logistics and Warehousing

Automated guided vehicles (AGVs) and robotic systems streamline inventory management and delivery.

4.5 Defense and Security

Robots are used for surveillance, bomb disposal, and disaster response.

4.6 Domestic and Service Robots

Robotic vacuum cleaners and service robots improve convenience in homes and public spaces.

5. Impact on Employment and Society

Automation replaces repetitive and hazardous jobs while creating new opportunities in robotics programming, system maintenance, and AI development. Workforce reskilling and education are essential to adapt to technological transformation.

6. Advantages of Robotics and Automation

- Increased productivity and efficiency
- Improved precision and quality control
- Enhanced workplace safety
- Reduced operational costs
- 24/7 operational capability
- Reduced human error

7. Challenges and Limitations

Despite benefits, robotics and automation present several challenges:

- High initial implementation cost
- Job displacement and workforce reskilling needs
- Security vulnerabilities and cyber threats
- Ethical concerns regarding autonomous decision-making
- Maintenance and technical complexity

8. Future Trends in Robotics and Automation

8.1 Collaborative Robots (Cobots)

Robots designed to work safely with humans.

8.2 Autonomous Vehicles and Drones

Self-driving vehicles and aerial drones will transform transportation and delivery.

8.3 AI-Powered Smart Factories

Factories will use predictive analytics and automation for intelligent production.

8.4 Service and Healthcare Robotics

Robots will support aging populations and assist in medical care.

8.5 Humanoid Robots

Advanced humanoid robots are being developed for service and interaction tasks.

9. Conclusion

Robotics and automation are reshaping the modern world by improving efficiency, safety, and productivity across industries. While challenges such as job displacement and ethical considerations remain, the benefits far outweigh the limitations. With continued innovation and responsible implementation, robotics and automation will play a crucial role in building smart industries, sustainable economies, and improved quality of life.

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Applications of Number Theory in Machine Learning and Artificial Intelligence

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Abstract

AI (Artificial Intelligence) is now one of the most revolutionary technologies of the 21st century that touch upon such domains as healthcare, finances, cybersecurity, and robotics. Although AI is usually also linked to machine learning, neural networks, and big data, the importance of mathematical foundations cannot be underestimated. The number theory is another valuable but frequently neglected branch of mathematics that the AI uses. Number theory concerns properties and relations of integers, prime numbers, modular arithmetic and cryptographic constructions. These ideas are important in data security, hashing algorithms, random number generation and optimization methods in AI systems. This paper discusses the use of number theory in artificial intelligence: cryptography, hash functions, pseudorandom number generators, data encoding and optimization algorithms. The paper emphasizes the role of classical ideas in number theory in the architecture of modern AI systems and their role in building secure and efficient intelligent systems.

Keywords: Number Theory, Machine Learning, Artificial Intelligence, Applications

1. Introduction

Artificial Intelligence (AI) is a novel development in the realm of computational technologies that allow machines to learn trends, predict actions, and do other activities previously dominated by human intelligence. Math concept The AI systems are highly dependent on mathematical concepts, including linear algebra, probability theory, calculus, and optimization. Nevertheless, another significant branch of mathematics that can be useful to AI is number theory.

Number theory is a branch of mathematics which examines integers and their characteristics. Prime numbers, modular arithmetic, divisibility, and number

sequences are examples of concepts that find important uses in computer science and AI systems. In the past number theory was a purely theoretical discipline. Nowadays, it is important in cryptography, cybersecurity, and data encryption as well as algorithm design.

The paper will discuss the application of number theory in AI usage, its significance in secure computing, optimization algorithms, and data processing methods.

2. Basic Ideas of Number Theory.

It is necessary to be familiar with some important concepts of number theory before mentioning applications of its use in AI-related systems.

2.1 Prime Numbers

Prime numbers are numbers that are larger than one, but whose only two possible divisors are one and the number itself. Prime numbers are essential in cryptographic keys like the RSA encryption version, which secures the transmission of data in applications using the AI.

2.2 Modular Arithmetic

In modular arithmetic, one does calculations with the rest of the result of a division. It is usually written as: $a \equiv b \pmod{n}$

Modular arithmetic is common in cryptography, hash functions, and blockchain systems that enable the use of AI to make decisions.

2.3 Greatest Common Divisor (GCD)

The largest number that is common to a pair of integers is the greatest common divisor. Encryption and key generation requires efficient algorithms like the Euclidean Algorithm.

2.4 Diophantine Equations

They are integer equations and are applied to optimization and constraint-based artificial intelligence.

Application in Artificial Intelligence Role of Number Theory. The field of number theory is relevant to a number of fields of AI development. These are information protection, hash, pseudo random number, and distributed computer.

3. Applications of Number Theory in AI

3.1 Cryptography and Secure AI Systems

Cryptography is one of the largest uses of number theory in AI. AI systems are often dealing with big data sets that hold confidential data. It is necessary to protect this information.

Modular arithmetic and prime numbers are important in public-key cryptographic systems like RSA. Large prime numbers are utilized in the

encryption and decryption keys in RSA encryption. RSA security is based on the hardness of factoring large composites.

AI-based applications like medical diagnostics, self-driving cars, and financial forecast models commonly have networks as their communication medium. The security in the communication between these systems is provided by number-theoretic cryptography.

For example: Secure medical AI systems use encryption to protect patient data., AI-based financial systems rely on cryptographic protocols for secure transactions.

3.2 Random Number Generation

Artificial intelligence algorithms often require random or pseudo-random numbers. These numbers are used in: Neural network weight initialization, Stochastic gradient descent, Genetic algorithms

Monte Carlo simulations

Many pseudorandom number generators rely on number-theoretic structures such as modular arithmetic.

A simple example is the Linear Congruential Generator (LCG):

$$X_{n+1} = (aX_n + c) \bmod m$$

Where a is a multiplier, c is an increment, m is a modulus

These sequences generate pseudo-random numbers used in AI training processes.

3.3 Blockchain and Decentralized AI

Blockchain technology relies heavily on number theory and cryptography. In decentralized AI systems, blockchain ensures secure and transparent data sharing. Applications include: AI data marketplaces, Decentralized machine learning, Secure AI model sharing

3.4 Optimization Algorithms

Some optimization algorithms used in AI incorporate number-theoretic methods. Integer programming, modular arithmetic constraints, and combinatorial optimization problems often arise in AI model training.

4 Numerical Example

Consider a simple modular arithmetic example used in hashing.

Let a hash function be defined as: $h(x) = x \bmod 7$

Suppose we have the following data values:

Data	Hash Value
15.0	1.0
23.0	2.0
31.0	3.0

42.0	0.0
------	-----

This hashing technique allows efficient indexing of large datasets in AI systems.

4.1 Python Implementation Example

Below is a simple Python program demonstrating pseudorandom number generation using modular arithmetic.

```
def linear_congruential_generator (seed, a, c, m, n):
    numbers = []
    x = seed
    for i in range(n):
        x = (a * x + c) % m
    numbers.append(x)
    return numbers
seed = 7.0
a = 5.0
c = 3.0
m = 16.0
n = 10.0
random numbers = linear_congruential_generator (seed, a, c, m, n)
print ("Generated Numbers:")
print (random numbers)
```

4.2 Output

[6.0, 1.0, 8.0, 11.0, 10.0, 5.0, 12.0, 15.0, 14.0, 9.0]

These pseudo-random numbers can be used in AI algorithms for simulations and stochastic optimization methods.

5. Results and Discussion

The paper shows that number theory is fundamental to the different applications of AI. AI-based healthcare and financial systems use cryptographic systems to guarantee the privacy of data. The reason why hashing techniques enhance efficiency in machine learning algorithms is that they reduce high dimensional feature spaces. Modular arithmetic-based pseudorandom number generators have been used to implement stochastic learning algorithms like stochastic gradient descent and genetic algorithms. Moreover, number theory is also involved in the new technologies like blockchain-based AI platforms.

6. Conclusion

Number theory, a traditional area of pure mathematics, is useful in artificial intelligence today. Ideas like prime numbers, modularity, and integer

designs form the basis of cryptography, hashing, pseudorandom number generators, and blockchain technologies. These applications are essential in providing security of data, efficiency of computing, and stable AI systems. With the ever-growing field of AI, including sensitive fields like healthcare and finance, number theory will be a critical part of creating secure and robust intelligent systems. More studies that combine number theory with machine learning and deep learning systems might result in new algorithms and enhanced AI systems.

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Game Theory in Artificial Intelligence: Nash Equilibria in Multi-Agent Reinforcement Learning

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Abstract

Game theory provides a formal framework for modeling strategic interactions between rational decision-makers. In the context of Artificial Intelligence (AI), game theory plays a crucial role in multi-agent systems (MAS), reinforcement learning (RL), and competitive decision-making environments. This paper explores the application of Nash Equilibria in multi-agent reinforcement learning (MARL), examining how AI agents can learn optimal strategies through interaction with other agents in both cooperative and competitive settings. We discuss the mathematical formulation of Nash Equilibria, the challenges in applying game theory to MARL, and the impact of these concepts on real-world AI applications such as autonomous systems, robotics, and adversarial gaming. Finally, we review recent advances in AI that utilize game-theoretic approaches for strategic decision-making and highlight future directions for research.

1. Introduction

Game theory is a mathematical framework used to model decision-making in situations where multiple agents interact, each with their own objectives. In multi agent systems, game theory provides the foundation for designing algorithms where multiple intelligent agents need to make decisions that affect not only their outcomes of other agents.

In Artificial Intelligence (AI), game theory has been particularly influential in multi-agent reinforcement learning (MARL), where agents must learn optimal strategies in competitive or cooperative environments. One of the central concepts in game theory is the “Nash Equilibrium (NE)”, which represents a state in a game where no player can benefit by changing their strategy, assuming the strategies of the other players remain unchanged. This paper explores how Nash Equilibria are used in AI to model and solve complex decision-making problems.

2. Mathematical Background: Game Theory and Nash Equilibrium

➤ Classical Game Theory

A “game” is defined by a set of players, strategies, and payoffs. In a non-cooperative game, each player aims to maximize their own payoff without cooperation with other players. A general two-player, non-zero-sum game can be defined by the following elements:

A set of players ($N = (1, 2, \dots, n)$),

A set of strategies (S_i) for each player (i),

A payoff function $u_i((s_1, s_2, \dots, s_n))$, which gives the payoff to player (i) given the strategies (s_1, s_2, \dots, s_n) , chosen by all players.

The concept of ‘Nash Equilibrium (NE)’ is defined as follows: A strategy profile

$\mathbf{s}^* = ((s_1^*, s_2^*, \dots, s_n^*))$ is a Nash Equilibrium if, for each player (i), no unilateral change in strategy can improve their payoff: $u_i((s_i^*, s_{-i}^*)) \geq u_i((s_i', s_{-i}^*))$ for all $s_i' \in S^i$.

In other words, each player's strategy is optimal given the strategies of the other players.

3. Nash Equilibrium in Multi-Agent Reinforcement Learning (MARL).

In the context of MARL, Nash Equilibrium can be interpreted as the set of strategies that maximize an agent's reward, given that other agents are simultaneously maximizing their rewards. In reinforcement learning, each agent learns a policy ($\pi_i(s)$) that maximizes its own expected cumulative reward (R_i). The goal is to find a stable set of policies, where no agent can improve its reward by unilaterally changing its policy, thus achieving a Nash Equilibrium. For a multi-agent environment, the Q-function ($Q_i(s, a)$) of each agent (i) is used to represent the expected reward for taking action (a) in state (s) and following the optimal policy thereafter. The goal of MARL is for each agent to learn a policy such that its action maximizes its expected reward, given the policies of other agents in the system.

4. Application of Nash Equilibria in AI-

- i. **Multi-Agent Reinforcement Learning (MARL)** - In MARL, each agent learns through interactions with the environment and with other agents. The primary challenge in MARL is that the environment is partially controlled by other agents, leading to dynamic interactions that require agents to continuously adapt. Nash Equilibrium provides a mathematical model for agents to stabilize their strategies in this dynamic environment.
 - ii. **Cooperative Multi-Agent Systems-** In a cooperative multi-agent system, agents work together to maximize a common objective. While this can sometimes lead to a single Nash Equilibrium, cooperation among agents can also lead to the emergence of sub-optimal equilibria due to the need to balance exploration and exploitation. In such systems, techniques like joint action learning and value decomposition are used to break down the common objective into individual rewards, guiding agents towards a cooperative Nash Equilibrium.
 - iii. **Competitive Multi-Agent Systems-** agent's gain is another's loss. For example, in adversarial settings like gaming or autonomous vehicle In competitive environments, agents may have conflicting objectives, as in a zero-sum game, where one guide agents to strategic play, where no agent can gain by deviating unilaterally from their equilibrium systems, agents learn optimal strategies in the presence of opposition. In such settings, Nash Equilibria guide agents to strategic play, where no agent can gain by deviating unilaterally from their equilibrium strategy.
- **Application Example: Adversarial Gaming**
Games like Poker Go, or Chess provide natural settings for applying game theory. In adversarial gaming, agents can use reinforcement learning techniques combined with game-theoretic principles to optimize their strategies. A classical example is AlphaGo, where deep reinforcement learning and Monte Carlo Tree Search were used to develop an AI capable of achieving near-perfect play In Go, essentially learning an approximation of a Nash Equilibrium in the game.

5. Real-World AI Application

Beyond gaming, game theory plays a crucial role in a variety of real-world applications:

- i. **Autonomous vehicles:**
In traffic or navigation scenarios, self-driving cars need to make decisions based on the actions of other vehicles. Nash Equilibria can help optimize

the driving strategies to avoid collisions while ensuring efficient traffic flow.

- ii. **Robotics:** In multi-robot systems, Nash Equilibria can guide robots to perform cooperative tasks, like exploration, or to avoid interference with each other.
- iii. **Economics and Auctions:** In market-based AI systems or digital auctions, agents (buyers and sellers) strategize to maximize their profits based on the strategies of others. Game theory helps model these interactions and find equilibria that maximize efficiency.

6. Challenges and Limitations:

While Nash Equilibria provide a useful tool for modeling strategic behavior, applying them in multi-agent systems comes with several challenges:

- i. **Non-Stationary Environments:** In MARL, the strategies of other agents are constantly evolving, making it difficult for agents to converge to a stable equilibrium,
- ii. **Multiple Equilibria:** In some games, multiple Nash Equilibria exist, and choosing the right equilibrium can be difficult, especially when these equilibria have different payoffs.
- iii. **Computational Complexity:** Computing Nash Equilibria can be computationally expensive, particularly in games with many players or complex action spaces.

7. Recent Advances in Game-Theoretic AI-

Recent advancements in AI have leveraged techniques from game theory to improve agent decision-making:

1. **Deep Q-Learning in MARL:** Deep Q-Networks (DQNs) have been integrated into MARL settings, allowing agents to learn Nash Equilibrium through deep reinforcement learning (DRL) techniques.
2. **Mean Field Games (MFGs):** MFGs offer an approach for analyzing the equilibrium in large populations of agents, improving scalability in environments with many agents.
3. **Evolutionary Game Theory:** Evolutionary algorithms are used to model the development of strategies over time, providing insights into the dynamics of learning in competitive environments.

8. Conclusion-

Game theory, and specifically Nash Equilibria, offers a powerful framework for understanding and optimizing decision-making in multi-agent systems. As AI continues to grow in complexity, especially in competitive and collaborative environments, game-theoretic models like Nash Equilibria provide key insights into how agents can learn optimal strategies through interaction. Future research could explore more efficient algorithms for computing equilibria in large-scale systems, the integration of advanced learning methods like deep reinforcement learning with game theory, and the development of scalable solutions for real-world applications in robotics, autonomous systems, and economics.

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Learning And Symmetry: Artificial Intelligence Applications of Group Theory

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Abstract

The scope of Artificial Intelligence (AI) has grown quickly over the past few decades with machines now being able to accomplish complex tasks including image recognition, natural language processing, robotics, and autonomous decision-making. Mathematics is a cornerstone of AI algorithms, especially of linear algebra, probability theory, optimization, and abstract algebra. The most powerful tool of studying symmetry and transformations in data is given by one of them, group theory, a subdiscipline of abstract algebra. The paper elaborates the use of group theory in artificial intelligence in the context of the application in neural networks, computer vision, pattern recognition, robotics, and cryptographic security. The paper sheds light on the efficiency and generalization achievements of symmetry-based learning. Moreover, an example of numerical specifics and computational proofs is introduced to demonstrate the expediency of the group-theoretic structures in the AI models. The findings indicate that group theory can be used to improve performance and interpretability in machine learning models in a considerable way.

Introduction

The artificial intelligence has revolutionized different sectors including healthcare, finances, transport and farming. AI systems are based on mathematical basis to design algorithms that have ability to learn with data. Group theory is one of the least-known and most extremely significant mathematical systems in AI, the study of algebraic systems that characterize symmetry and transformations.

Group theory A group theory was initially developed by mathematicians working on the study of equations of polynomials and geometrical transformations in the 19th century. A set of elements that has a binary operation

and that satisfies four properties which include closure, associativity, identity and inverse is defined as a group. The buildings enable mathematicians to examine changes in a systematic way.

Symmetries in artificial intelligence as in any dataset, there are symmetries in numerous datasets. As an example, a picture of an object does not change with a rotation or a movement. The old ways of machine learning would need big datasets to learn these variations. Nonetheless, group theory allows the development of models which are aware of such transformations.

The paper presents the mathematical basis of group theory and its application in various AI areas such as:

- Robotics and motion planning
- Computer vision
- Deep learning architectures
- Pattern recognition
- Cryptography and data security

2. Mathematical Background of Group Theory

A group is an algebraic structure defined as a pair $(G, *)$ where G is a set and $*$ is a binary operation satisfying the following properties:

Closure: If $a, b \in G$, then $a * b \in G$.

Associativity : $(a * b) * c = a * (b * c)$

Identity element : There exists $e \in G$ such that $a * e = e * a = a$

Inverse element: For every $a \in G$, there exists a^{-1} such that $a * a^{-1} = e$

Example: Rotation Group

Consider rotations of a square. The possible rotations are: $G = \{0^\circ, 90^\circ, 180^\circ, 270^\circ\}$ These rotations form a group under composition. This group is called the cyclic group C_4 .

Such symmetry groups appear naturally in many AI problems, particularly in image recognition.

3. Role of Symmetry in Artificial Intelligence

Symmetry is essential in the process of learning characteristics of information. For example:

Even with the slight rotation of a cat, it is still a cat. The same handwritten number does not change during translation. Molecules are symmetrically invariant. The classical neural networks consider every transformed example as a new training sample. Nonetheless, group theory enables AI systems to represent invariance and equivariance, i.e. the model is

aware of transformations that do not alter the underlying object. Advantages: Smaller training data needed, Better generalization, Effective computation, Improved model explainability.

4. Applications of Group Theory in AI

4.1 Group Convolutional Neural Networks (G-CNN)

Convolutional neural networks are widely used in image recognition. However, standard CNNs are only translation invariant. They struggle with rotations and reflections.

4.2 Computer Vision

Group theory is widely used in computer vision tasks such as: Object recognition, Image classification, Face detection, medical image analysis

4.3 Robotics and Motion Planning

Robotics involves knowledge of the spatial transformations including: Translation, Rotation.

4.4 Pattern Recognition

Pattern recognition systems making use of group theory occur when objects are presented in various orientations.

4.5 Cryptography and Secure AI

Group theory is also applied in secure communication system in the uses of AI. Most cryptographic systems make use of algebraic structures including: cyclic groups, elliptic curve groups.

5. Numerical Example

Consider a simple example of rotational symmetry in image recognition.

Suppose we have an object represented by coordinates: $(1,0)$

If we rotate it by 90° the new coordinate becomes $(0,1)$ Similarly, $180^\circ \rightarrow (-1,0)$, $270^\circ \rightarrow (0,-1)$ These transformations form a group.

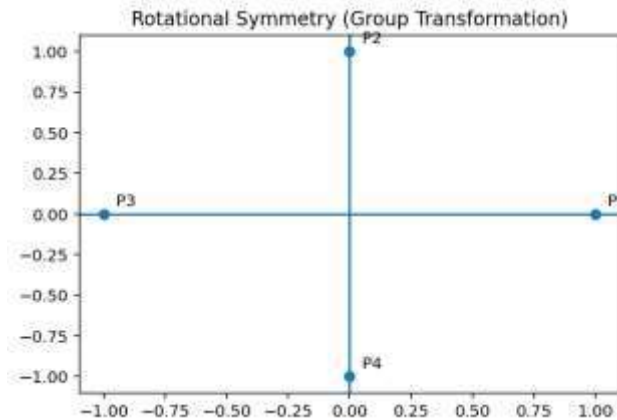
In machine learning, instead of learning each orientation separately, a group-theoretic model learns all transformations simultaneously.

6. Python Demonstration

The following Python code demonstrates a simple rotational transformation using matrices.

```
import numpy as np
import matplotlib.pyplot as plt
point = np.array([1,0])
R90 = np.array([[0,-1],[1,0]])
R180 = np.array([[ -1,0],[0,-1]])
```

```
R270 = np.array([[0,1],[-1,0]])
p1 = point
p2 = R90 @ point
p3 = R180 @ point
p4 = R270 @ point
points = np.array([p1,p2,p3,p4])
plt.scatter(points[:,0],points[:,1])
plt.axhline(0)
plt.axvline(0)
for i,p in enumerate(points):
    plt.text(p[0]+0.05,p[1]+0.05,f"P {i+1}")
plt.title("Rotational Symmetry (Group Transformation)")
plt.show()
```



7. Results and Discussion

Group theory has a number of benefits in model design and performance when implemented in artificial intelligence. Symmetry-based learning helps neural networks to identify patterns without consideration of the orientation or transformation. This makes the training data less redundant and enhances model generalization. Group convolutional networks are more effective than traditional convolutional neural networks in applying their use in computer vision tasks where an image is used based on its rotation. On the same note, the group-theoretic approaches are advantageous to robotics applications which model spatial transformations well. The illustrative example of simple rotational groups illustrates the manner of transformation of data. By instilling such transformations in the machine learning models, the network is more efficient to identify patterns.

8. Conclusion

Group theory is a very useful mathematical tool in describing symmetry and transformations in artificial intelligence. With the integration of algebraic structures in machine learning models, researchers are in a better position to come up with algorithm models that are stronger, more efficient and interpretable. Group theory has been applied in AI in the fields of convolutional neural networks, computer vision, robotics, pattern recognition, and cryptographic security. The direct encoding of transformation invariance into learning models allows achieving training complexity and performance a greater impact. Future research directions are to devise more sophisticated equivariant neural networks, the use of Lie groups in deep learning systems, and the use of group theory in novel AI tasks, including quantum machine learning and autonomous systems. The inclusion of the abstract mathematical principles such as group theory will be an important provision in the construction of more intelligent and trustworthy systems as the sphere of artificial intelligence keeps developing.

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Applications of Calculus in Artificial Intelligence and Machine Learning Training Models

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Abstract

Artificial Intelligence (AI) has now become one of the most disruptive technologies of the 21st century. Numerous fields in mathematics are useful in AI, such as linear algebra, probability, statistics, and calculus. Of them, calculus is a core part of machine learning algorithm design and optimization. Derivatives, gradients, partial derivatives, integrals and optimization methods are some of the concepts that are used in training models and enhancing performance of predictive models. This paper will discuss the main uses of calculus in artificial intelligence with a special focus on optimization, neural networks, gradient descent algorithms, deep learning, and probabilistic models. An example is also provided in Python to show how calculus-based optimization makes machine learning models better. The paper provides significant insights into the use of calculus as the basis of the contemporary AI frameworks.

Keywords: Calculus, Artificial Intelligence, Mathematics, Machine Learning, Optimization

1. Introduction

Artificial Intelligence (AI) is the process of developing computer systems that are capable of executing activities, which are conventionally done by people of good intelligence, including learning, reasoning, pattern recognition, and decision-making. Machine learning is one of the primary branches of AI that enables the system to learn through data and become more efficient without being programmed. AI is based on mathematics. Although linear algebra is applicable in the models and the representation of data, probability and statistics are concerned with the uncertainties of prediction. Nevertheless, calculus offers the means to study change and optimize functions. Machine learning algorithms most

often use calculus to optimize the error functions and enhance the performance of the model.

As an illustration, neural networks learn by modifying weights in a bid to minimise prediction error. It trains the parameters using derivatives and calculus gradients to find the direction in which the parameters should evolve. Methods of optimization including gradient descent, stochastic gradient descent and backpropagation are purely calculus based. The paper discusses the use of calculus in artificial intelligence with specific consideration to the application of derivatives, partial derivatives, and integrals in machine learning models, neural networks, and optimization problems.

2. Role of Calculus in Artificial Intelligence

2.1 Derivatives and Optimization

In machine learning, the main objective is to minimize a loss function that measures the difference between predicted and actual values.

If the loss function is $L(w)$ where w represents model parameters, calculus helps determine how the loss changes with respect to w .

The derivative $\frac{dL}{dw}$ indicates the direction in which the loss function increases or decreases. By moving parameters in the opposite direction of the derivative, the algorithm reduces the loss.

This principle forms the basis of gradient descent, one of the most widely used optimization methods in AI.

2.2 Gradient Descent Algorithm

Gradient descent is an iterative optimization algorithm used to minimize cost functions in machine learning.

The update rule is $w_{\text{new}} = w_{\text{old}} - \alpha \frac{dL}{dw}$ Where w = model parameter and α = learning rate

$\frac{dL}{dw}$ = derivative of loss function

The derivative guides the direction of parameter updates. Without calculus, it would be impossible to determine how to adjust parameters efficiently.

Gradient descent is used in many algorithms including Linear Regression, Logistic Regression Neural Networks, Deep Learning models.

2.3 Chain Rule in Backpropagation

Back propagation is used to train deep neural networks by computing gradients layer by layer.

Suppose the output of a network depends on multiple functions: $y = f(g(x))$

Using the chain rule: $\frac{dy}{dx} = \frac{dy}{dg} * \frac{dg}{dx}$

This allows neural networks to propagate error signals backward and update each layer's weights. Backpropagation is essential for training deep learning models used in: Image recognition, Natural language processing, Speech recognition, Autonomous vehicles

2.4 Integrals in Probabilistic AI Models

Integrals are also important in AI, especially in probabilistic modeling and Bayesian inference.

In probability theory, integrals are used to compute expected values: $E[X] = \int x f(x) dx$

This is used in Bayesian machine learning, Reinforcement learning, Probabilistic graphical models

Integrals also help compute likelihood functions and posterior distributions.

3. Numerical Example

Consider a simple dataset for linear regression.

X	Y
1	2
2	3
3	5
4	7
5	11

We assume the linear model $y = wx + b$

The loss function (Mean Squared Error) is $L = \frac{1}{n} \sum (y_i - y^i)^2$ To minimize this loss, we compute derivatives with respect to w and b. Using gradient descent, parameters are updated until the error becomes minimal.

4. Python Implementation

```
import numpy as np
import matplotlib.pyplot as plt
x = np.array([1,2,3,4,5])
y = np.array([2,3,5,7,11])
w = 0
b = 0
```

```
learning_rate = 0.01
epochs = 100
n = len(x)
loss_list = []
for i in range(epochs):
    y_pred = w*x + b
    loss = np.mean((y - y_pred)**2)
    loss_list.append(loss)
    dw = (-2/n)*np.sum(x*(y - y_pred))
    db = (-2/n)*np.sum(y - y_pred)
    w = w - learning_rate*dw
    b = b - learning_rate*db
print("Weight:", w)
print("Bias:", b)
plt.scatter(x,y)
plt.plot(x,w*x+b)
plt.title("Regression Line using Gradient Descent")
plt.show()
plt.plot(loss_list)
plt.title("Loss Reduction during Training")
plt.show()
```

This program uses calculus-based derivatives to optimize the regression model. The loss decreases gradually, demonstrating how calculus helps AI models learn from data.

5. Results and Discussion

The implementation illustrates the accuracy of models with the use of calculus-based optimization. The gradient descent is a gradual associated reduction of the loss function by updating parameters with derivatives. The model has provided a regression line that fits the data set very well hence it has been trained successfully. The plot of losses indicates that the error is minimizing with the number of iterations, and this makes it clear that the optimization process is approaching to the optimal solution. This explains why calculus is relevant to make changes in the parameters in machine learning models. In scale AI models like deep neural networks, derivative and gradient optimization of millions of parameters is performed at the same time. Training of such models would be computationally inefficient, or impossible, without calculus. Moreover, advanced optimization algorithms like Adam, RMS Prop, and Adagrad can be formulated

using calculus, and they can be more efficient, faster, and stable in a deep learning system.

6. Conclusion

The mathematical technique of calculus plays a central role in artificial intelligence and machine learning. Derivatives, gradients, partial derivatives and integrals, among others, allow the optimization of any complex model and efficient learning of data. Gradient descent and backpropagation algorithms are algorithms that heavily depend on calculus to adjust model parameters and minimise error functions. The numerical example and Python code show that calculus-based methods enhance predictive performance of machine learning models. With the further development of AI, calculus will still be necessary to create more sophisticated algorithms and optimization of neural networks of large scale. Future studies can examine better optimization methods, hybrid methods, which integrate fuzzy logic and calculation-based learning, and other uses in new areas like explainable AI and quantum machine learning.

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A Fuzzy Logic-Based Decision Support System for Engineering College Admissions in India

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Abstract

The current process of selecting the right engineering college is often a complex and multidimensional decision-making process for prospective students and their parents. Every student prefers to seek admission to a college that has a good placement record, cut-off trends, and high-quality institutional infrastructure. In Maharashtra, centralized engineering admissions are conducted through both state-level (MHT-CET) and national-level (JEE Main and Advanced) entrance examinations, requiring candidates to prioritize colleges based on historical cut off data for various programs. However, manually selecting a suitable college from nearly 300 institutions within a preferred region is a challenging and uncertain task.

The study proposes a Graphical User Interface (GUI)-based decision support system that generates a personalized list of college preferences that minimizes the reliance on manual research and third-party counselling services. The system employs a fuzzy logic-based approach utilizing the Mamdani inference mechanism and centroid defuzzification method to compute a suitability score for each college. By incorporating parameters such as the candidate's state merit rank, category, gender, preferred branch, city, and college, the system evaluates and predicts the probability of admission using linguistic variables-Very High, High, Medium, and Low. This fuzzy inference-based framework enhances transparency, efficiency, and personalization in the college selection process for engineering aspirants.

Keywords: Fuzzy Logic, Admission Prediction, Engineering, Mamdani Inference
MSC Classification: 03B52, 03E72, 93C42

Introduction

Selecting an appropriate college has emerged as a critical and multifaceted decision in shaping a student's academic and professional trajectory. In today's competitive educational landscape, students are required to make well-informed academic choices that not only align with their personal interests but also anticipate evolving industry demands and future employment trends. This study focuses on the engineering admission process in Maharashtra, primarily governed by the Maharashtra Health and Technical Common Entrance Test (MHT-CET). The MHT-CET serves as the centralized admission mechanism, providing a unified platform through which students can apply to engineering and other professional programs. A key advantage of this system is its transparency, as the government releases comprehensive raw score data, enabling students and their families to compare opportunities across institutions and programs based on historical trends. Despite these strengths, the admission process presents significant challenges. The proliferation of colleges, diverse branches of study, and complex reservation policies generate a substantial volume of raw data. For many students and parents, navigating this information can be overwhelming, increasing uncertainty in decision-making. Consequently, the core challenge is not the lack of data, but the absence of an effective decision-support mechanism that can provide personalized guidance and strategic insights. This paper proposes an intelligent decision-support framework based on fuzzy logic to assist students and parents in creating optimized college preference lists according to state merit rank. Traditional decision-making approaches typically rely on a binary comparison of the student's rank against institutional cut-offs. In contrast, the proposed model addresses the inherent uncertainty in admission decisions by assigning a graded suitability score that reflects a student's rank relative to multiple factors, including entrance exam performance, cut-off trends, branch and college preferences, and geographic considerations. The system integrates a fuzzy logic engine with a multi-criteria filtering model to generate dynamic, personalized recommendations. The framework preprocesses official admission cutoff data and augments it with forward looking insights from industry trends to maintain a comprehensive and up-to-date database. The fuzzy logic engine evaluates the MHT-CET rank, applies meaningful constraints such as city, gender, and reservation category, and produces a suitability score that accommodates imprecision while recognizing compensatory strengths. This score is iteratively refined through the multi-criteria filtering model, incorporating

sequential constraints based on students' academic and geographical preferences. Several researchers have previously used the fuzzy logic-based control approaches for prediction and decision-making contexts [4, 6, 7]. The study presents prediction of engineering admission using fuzzy logic control, implemented in Python. In the first stage, data collection and preprocessing are performed on unstructured MHT-CET engineering admission data. In the second stage, a fuzzy logic control system is applied, with the input variable being the rank gap and output variable being the suitability score. The system incorporates fuzzy rules and defuzzification methods to provide a structured and accurate prediction. Future work will focus on improving prediction accuracy by incorporating additional factors such as institutional placement records, infrastructure quality and alumni feedback. Furthermore, a web-based platform will be developed for easy access for all candidates.

Related Work

The admission prediction model serves as a valuable tool for both educational institutions and prospective students. It facilitates strategic planning, enhances student engagement, supports institutional development, and contributes significantly to the advancement of modern education systems. The integration of computational intelligence for predicting admissions and institute allocation has emerged as an important research focus. Previous studies have primarily employed algorithms such as Artificial Neural Networks, Linear Regression, Random Forest, and Logistic Regression. However, there is a lack of research on admission prediction in engineering education using fuzzy logic approaches. The present study addresses this gap by utilizing fuzzy logic to handle linguistic and uncertain information such as candidate rankings, city preferences, and program cut-off data to generate intelligent, flexible, and adaptive admission decisions.

The earliest significant work in this area was carried out by Lim and Qiu in 2001 [5], who proposed a fuzzy logic-based predictive connection admission control system for network traffic management. Their model utilized multi-step fuzzy predictors to anticipate future network loads, adapting bandwidth allocation dynamically while preserving Quality of Service (QoS) parameters such as latency and packet loss. Although developed for telecommunications, the core idea of making adaptive decisions under uncertainty laid the groundwork for later applications in education-related admission systems.

Several years later, Bhoite et al. (2018) [1] applied supervised learning algorithms to forecast engineering college admissions across 27 institutions. Their system processed 20 attributes per college using models such as Decision

Trees, K-Nearest Neighbour (KNN), Support Vector Machines (SVM), Random Forest, Naïve Bayes, Logistic Regression, and AdaBoost with Grid Search CV. Decision Trees produced the most accurate results, while Random Forest and SVM performed less effectively. Like fuzzy logic in networking, this approach relied heavily on dataset quality; however, the scope was geographically limited to a single city.

In [9], the authors proposed an admission prediction model that integrated both linear and non-linear machine learning algorithms, including Logistic Regression, Decision Tree, k-Nearest Neighbours (k-NN), and Naïve Bayes. The model aimed to estimate the likelihood of an unseen student being admitted to a university, demonstrating the effectiveness of combining multiple algorithms for predictive accuracy in college admission scenarios.

In [3], various machine learning algorithms such as KNN, Linear Regression, Ridge Regression, and Random Forest were used to predict the student admissions. This study focused on students seeking admission to abroad universities for higher education, particularly for students who want to pursue their master's in the United States.

Patel [10] developed a machine learning framework to predict admissions into various programs such as Master of Science (International), Master of Technology (India), and Master of Business Administration (India and International). The study utilized students' academic profiles and entrance exam scores as input features, with the dependent variable representing admission success. Key Performance Indicators (KPIs) were employed to evaluate and select the best-performing algorithm, including ensemble learning methods, to estimate the probability of admission as a continuous value between 0 and 1.

Priyadarshini et al. [11] focused on undergraduate admission using deep learning classifiers such as feedforward and input convex neural networks. Additionally, the interpretability module called LIME was incorporated, enabling the model to achieve 3.03% higher accuracy than existing machine learning based algorithms.

In [12], the authors focused on enhancing the accuracy of College Entrance Examination (CEE) result predictions to assist candidates in university application decisions. The study introduced machine learning techniques for admission research, with a particular emphasis on the AdaBoost algorithm, an ensemble learning method, to improve prediction performance and provide reliable guidance for prospective students.

Ahmed et al. [2] proposed a minimalistic regression model using only CGPA and GRE scores to predict graduate admissions. While mathematically

straightforward, it failed to capture the multifaceted nature of admission decisions, making it unsuitable for cases involving diverse candidate profiles. Mandavgane [8] used supervised and unsupervised machine learning algorithms such as Decision Trees, logistic Regression, KNN, and K-means clustering to predict engineering admissions. The model utilizes CET percentile, college location, and college rating to determine the best fit.

Table 1 Comparison of various algorithms based on prediction accuracy.

Sr. No.	Methodology / Algorithm Used	Accuracy (%)
1	Multiple Linear Regression with PCA	70
2	Support Vector Machine (SVM)	55
3	Random Forest Regression	66
4	Linear Regression	60.2
5	Ridge Regression	68
6	K-Nearest Neighbour (KNN)	62
7	Logistic Regression (LR)	55
8	Stacked Ensemble Learning	71

Methodology

The methodology for developing an engineering admission prediction model using a fuzzy logic control system consists of four fundamental stages: Fuzzification, Rule Base, Inference Engine, and Defuzzification. In the first stage, Fuzzification transforms crisp numerical inputs into corresponding fuzzy values. The second stage, Rule Base, comprises a set of IF-THEN rules that define the decision-making or control strategy. In the third stage, the Inference Engine processes the fuzzified inputs and applies the established rules to generate fuzzy output values. Finally, in the Defuzzification stage, these fuzzy outputs are converted back into crisp values to produce the final predictive result. The overall architecture of the fuzzy logic control system is illustrated below.

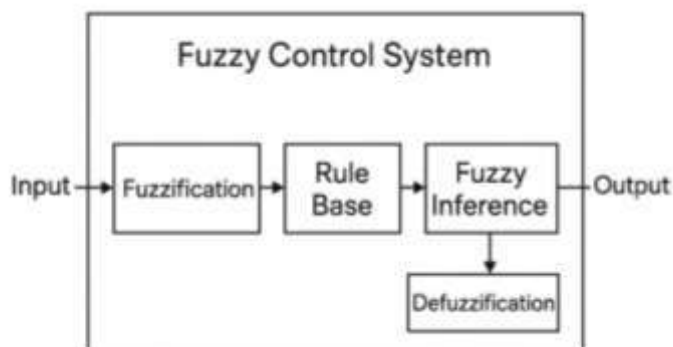


Fig. 1 Architecture of the Fuzzy Logic Control System for Engineering Admission Prediction

Data Collection and Preprocessing

The proposed data preprocessing pipeline automates the transformation of unstructured MHT-CET engineering admission data, originally available in PDF format, into a structured CSV representation suitable for analytical processing. The dataset was collected from the official MHT-CET cutoff reports published by the Directorate of Technical Education (DTE), Maharashtra. These reports contain tabular admission data representing college codes, branch codes, and cutoff ranks across multiple years.

The data extraction process begins with the use of the pdf plumber library in Python, which facilitates page-level text parsing and accurate table recognition by identifying textual coordinates. The extracted tabular information is exported to an intermediate CSV file using the functions pdf plumber.Open() and page.extracttext(). This step converts complex, human-readable tabular data into a machine-readable structure while preserving the sequential order of records.

Once converted, the CSV data is imported into a Pandas Data Frame for structured manipulation and refinement. Due to the inherent inconsistencies in PDF formatting, the extracted content often appears as a single text column. To resolve this, a preprocessing algorithm is applied to isolate this column, convert it into a list, and implement pattern-based string recognition. This technique identifies and separates distinct data entities based on numerical coding conventions: five-digit codes are recognized as college identifiers, while ten-digit codes correspond to branch identifiers. This heuristic effectively reconstructs the hierarchical relationship between colleges and their respective branches without relying on predefined delimiters.

branch_id	college_code	branch_code	branch_name	college_name	city	university	rank	DEFOFENS	EWS	GNT1H	GNT1O	GNT1S	GNT2H	GNT2O
100228100	1002	19110	Civil Engineering	Government College of Engineering, Amravati	Amravati	Sant Gadge Baba Amravati University	20	88030	90204	0	0	34281	0	0
100234210	1002	24210	Computer Science and Engineering	Government College of Engineering, Amravati	Amravati	Sant Gadge Baba Amravati University	20	27508	13851	0	0	18746	0	0
100234610	1002	24610	Information Technology	Government College of Engineering, Amravati	Amravati	Sant Gadge Baba Amravati University	20	33941	18299	0	0	22548	0	0
100229310	1002	29310	Electrical Engineering	Government College of Engineering, Amravati	Amravati	Sant Gadge Baba Amravati University	20	48986	49718	0	0	0	0	0
100237210	1002	37210	Electronics and Telecommunication Engg	Government College of Engineering, Amravati	Amravati	Sant Gadge Baba Amravati University	20	21431	23715	0	0	24939	0	0
100248410	1002	48410	Instrumentation-Engineering	Government College of Engineering, Amravati	Amravati	Sant Gadge Baba Amravati University	20	0	0	0	0	53013	0	0
100261210	1002	61210	Mechanical Engineering	Government College of Engineering, Amravati	Amravati	Sant Gadge Baba Amravati University	20	115556	75778	0	0	59809	0	0
100550310	1005	50310	Food Technology	Sant Gadge Baba Amravati University, Amravati	Amravati	Sant Gadge Baba Amravati University	94	0	82942	0	0	0	34208	0
100551710	1005	51710	Dit and Paints Technology	Sant Gadge Baba Amravati University, Amravati	Amravati	Sant Gadge Baba Amravati University	94	0	208134	0	0	0	0	0
100552410	1005	52410	Paper and Pulp Technology	Sant Gadge Baba Amravati University, Amravati	Amravati	Sant Gadge Baba Amravati University	94	0	0	0	0	0	0	0

Fig. 2 First 10 Rows of Normalized MHT-CET Admission Dataset.

Data-cleaning operations involve trimming whitespace and splitting lines using the delimiter “-” to separate codes from names. Colleges and branches are stored in separate lists, and duplicates are removed using Python’s set operations. This combined approach-leveraging pattern recognition, string manipulation, and data normalization ensures accurate and reproducible extraction. The resulting datasets are fully normalized and machine readable, forming a robust foundation for tasks such as data visualization, trend analysis, and machine learning? based prediction of engineering admissions.

Proposed Design Using Fuzzy Logic Control System

The Proposed Fuzzy Logic-Based Engineering Admission Prediction System was implemented using Python, integrating data processing, fuzzy inference, and an interactive graphical user interface (GUI) to provide personalized engineering college recommendations based on a student’s MHT-CET rank and preferences. The complete system architecture was developed using the pandas, NumPy, and scikit-fuzzy libraries, along with Tkinter for GUI design and Matplotlib for graphical analysis.

Dataset Loading and Normalization

The MHT-CET dataset, stored in a CSV format, is loaded into a Pandas Data Frame. Critical columns such as city, branch name, college name, and college code are standardized by converting text to lowercase and removing leading or trailing whitespace. Only the relevant cut-off categories are extracted, enabling dynamic filtering based on the student’s category (e.g., General, OBC, SC/ST). This preprocessing ensures uniformity and facilitates subsequent fuzzy computations.

Fuzzy Logic System Design

Input Variable-Rank Gap

The input variable rank gap is the difference between the actual MHT-CET state merit rank and the cutoff rank for a specific college-branch combination. This input is converted into fuzzy sets with three linguistic terms: Excellent, Good, and Average, over the range $[-10000, 15000]$. The linguistic variable Excellent corresponds to a large negative gap, where the candidate’s rank is significantly better than the cutoff, Good means the candidate’s rank is slightly better or near to the cutoff, and Average represents positive gaps, where the candidate’s rank is worse than the cutoff.

Table 2 Linguistic terms and their membership functions.

Linguistic Term	Membership Function	Interpretation
Excellent	$\text{trinf}([-10000, -5000, 0])$	Student rank much better than cut-off
Good	$\text{trinf}([-3000, 0, 3000])$	Rank close to cutoff
Average	$\text{trinf}([2000, 7000, 15000])$	Rank much worse than cutoff

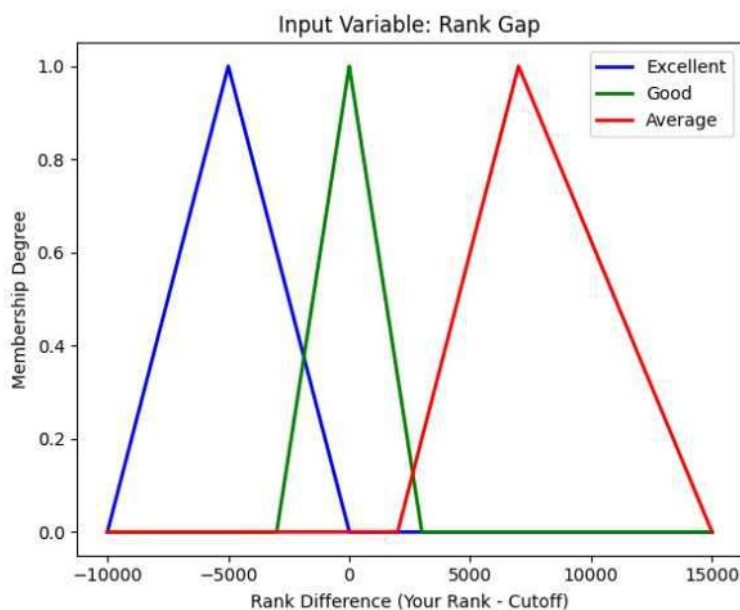


Fig. 3 Membership function of Input Variable.

Fuzzy Rule Base

The fuzzy inference system is governed by the set of fuzzy rules which are constructed using expert knowledge and quantitative analysis of admission trends. These fuzzy rules define the relationship between rank gap and suitability score.

Table 3 Fuzzy if then rules used for suitability evaluation.

Rule No.	Fuzzy Rule Description
Rule 1	If rank_gap is <i>Excellent</i> then suitability is <i>High</i>
Rule 2	If rank_gap is <i>Good</i> then suitability is <i>Medium</i>
Rule 3	If rank_gap is <i>Average</i> then suitability is <i>Low</i>

These fuzzy rules are based on the admission criteria, where a candidate with a significant rank gap indicates high suitability, a good gap indicates medium suitability, and an average gap results in low suitability.

Fuzzy Inference and Defuzzification

The proposed fuzzy control system uses the Mamdani fuzzy inference system, which consists of four main steps: fuzzification, which converts crisp input rank gap into fuzzy sets using a triangular membership function (refer to Figure 3), the second step, the application of a set of IF-THEN rules, the third, inference engine, which determines the fuzzy output by combining the rules and the fourth step, defuzzification, which converts the fuzzy output into a crisp suitability score using the centroid defuzzification method. The final centroid defuzzification output is calculated using the following formula:

$$x^* = \frac{\int x \cdot \mu_{\text{suitability}}(x) dx}{\int \mu_{\text{suitability}}(x) dx}$$

where x^* represents the final crisp suitability score for a college-branch combination, x denotes the output variable domain, and $\mu_{\text{suitability}}(x)$ represents the aggregated membership function of the suitability output.

Output Variable:

Suitability Score The output variable suitability measures admission likelihood on a 0-10 scale using the following membership functions:

Table 4 Linguistic terms for admission probability

Linguistic Term	Membership Function	Interpretation
Low	$\text{trimf}([0, 0, 5])$	Low admission probability
Medium	$\text{trimf}([4, 6.5, 8])$	Moderate admission probability
High	$\text{trimf}([7.5, 10, 10])$	High admission probability

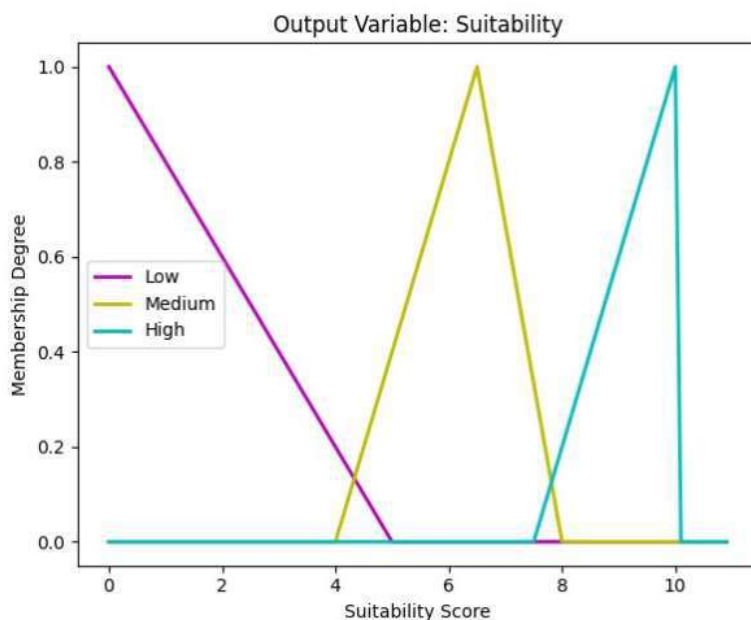


Fig. 4 Membership function of the Output Variable (Suitability Score).

The suitability score is computed using a Fuzzy Inference System (FIS), which effectively models uncertainty and nonlinearity in the admission decision-making process. The score interpretation is straightforward:

- **Higher score** (close to 10): Higher chance of admission (more suitable option)
- **Lower score** (close to 0): Lower chance of admission (less suitable option)

This fuzzy logic-based approach handles the uncertainties in college admission predictions and offers students better guidance for selecting their preferred colleges.

Categorization of Suitability Score

The suitability score, which is a crisp value computed from the defuzzification process, is then classified into five different categories: Very Low (or None), Low, Medium, High, and Very High, as shown in Table 5:

Table 5 Categorization of suitability scores.

Range	Category
$r > 9$ or $r = 0$	Very High
$6 < r \leq 9$	High
$3 < r \leq 6$	Medium
$0 < r \leq 3$	Low
Otherwise	Very Low / None

This categorization of suitability scores gives the candidate clear, transparent guidance for their college admission, transforming the numerical suitability score into meaningful admission probability categories.

Graphical User Interface (GUI) Development

The proposed fuzzy logic-based admission prediction model is presented using the user friendly and interactive graphical user interface of the Tkinter library in Python. The GUI worked as a front-end interface that takes candidate-specific parameters and displays recommended institutes for the admission. The interface allows the user to input the details such as category, gender, state merit rank, preferred branch, preferred city, and provides recommendations as per the branch and institute. These inputs are mapped to the stored dataset and then processed through the fuzzy control system. The GUI is designed based on human-computer interaction (HCI) principles, incorporating radio buttons, combo boxes, and entry fields for accurate and error-resistant data entry. Interface controls such as Get Suggestions, Clear, and Save Results perform real-time execution of fuzzy inference system, reset input fields, and generate predicted outcomes in CSV format for further analysis. The output displayed in a tabular Tree view structure, which includes College Name, College Code, Branch, Cutoff Rank, Fuzzy Suitability Score (ranging from 0-10), and Probability of Admission (Very High, High, Medium, or Low). To improve interpretability and decision making, a graphical visualization module incorporated using Matplotlib, which plots horizontal bar charts of fuzzy suitability scores alongside the corresponding cutoff ranks. This visualization further assists candidates in making informed admission decisions.

Overall, the graphical interface streamlines the computational complexity of the fuzzy inference system while allowing users to interact seamlessly with the predictive model. The integration of real-time processing, data visualization, and export capabilities significantly enhances the systems usability, reliability, and practical applicability.

Results

In Maharashtra, every year more than 2 lakh candidates apply for engineering admissions and only approximately 50% are able to take admission to their preferred branches. Even today, many students are unable to take admission due to lack of access to adequate resources, prior knowledge about institutes, and an understanding of previous years' cut-off trends. As a result, some students often end up securing admission in institutes that do not align with their preferences or

potential. The proposed fuzzy logic-based engineering prediction model mainly focused on guiding students to select the most suitable institute for admission according to their potential and preferred location, using state merit rank. The engineering admissions has limited rounds; hence, it is important to have a preferred list of colleges with a high probability of admission. The developed model significantly reduces the time required for manual searches of probable institutes and presents higher prediction accuracy as compared to existing engineering admission prediction models.

The following is a sample of the admission prediction model based on the fuzzy logic control for the preferred branch. The last column indicates the probability of admission according to the suitability score.

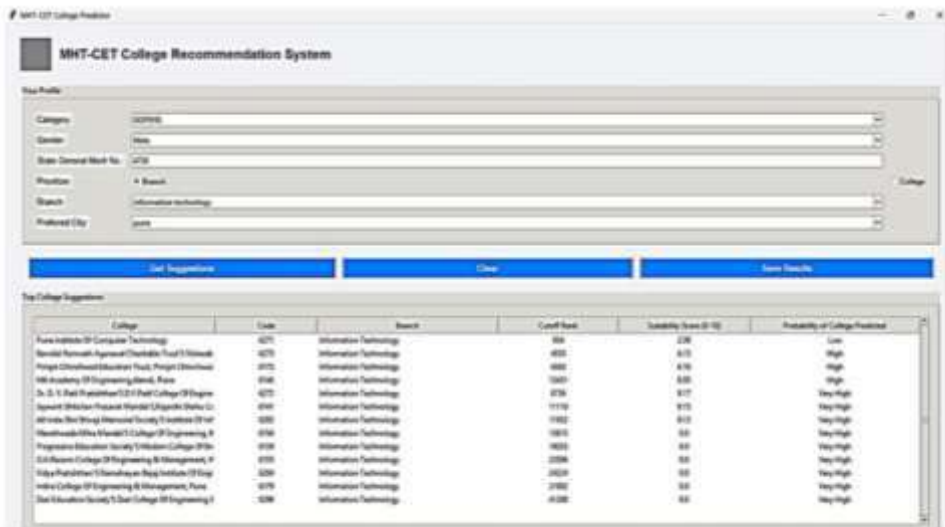


Fig. 5 Admission prediction based on branch preference.

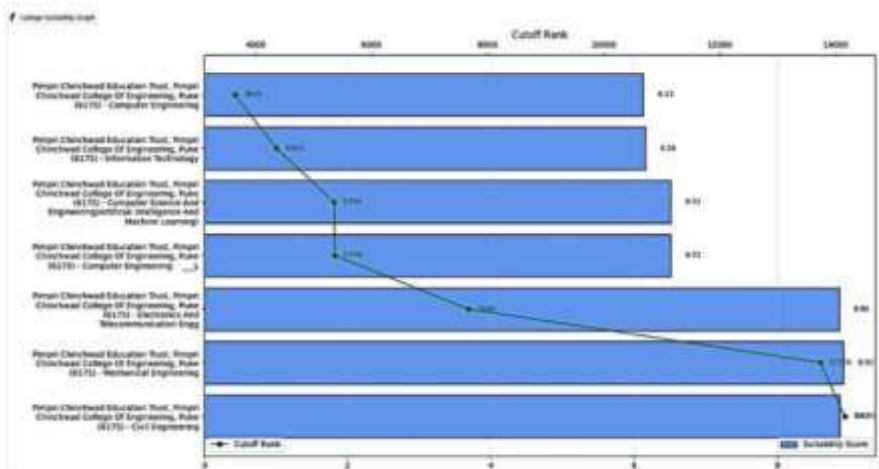


Fig. 6 Suitability scores for different college preferences.

In the existing model, a candidate can apply for betterment in the current college by selecting preferences for colleges, as shown below.

Conclusion

The present study proposes a fuzzy logic control system for predicting engineering admissions in Maharashtra. The system demonstrated high computational efficiency and predictive accuracy, with the fuzzy inference approach producing results closely aligned with actual admission patterns from the previous year. By effectively minimizing the manual effort required to identify potential institutes, the model offers a practical advantage over traditional rule-based or purely statistical approaches. Unlike conventional methods, the fuzzy logic framework accommodates uncertainty and imprecision inherent in human decision-making, resulting in superior predictive performance. The GUI-based system provides an intelligent and adaptive platform, enabling students to make informed and optimized admission choices by considering multiple factors, including merit rank, category, branch, and geographic preference. Evaluation on over 50 randomly selected samples showed that the model achieves an accuracy of 88%, underscoring its reliability and practical applicability in supporting student's admission decisions.

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Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication: All authors have read and approved the final manuscript and consent to its publication.

Data availability: The data used in this study were obtained from the official MHT-CET engineering allotment records for the previous academic year in Maharashtra. The dataset was used solely for research and educational purposes. Processed or anonymized data supporting the findings of this study are available from the corresponding author upon reasonable request.

Code availability: The Python code developed for implementing the fuzzy logic-based MHT-CET college recommendation system was written using open-source libraries including pandas, NumPy, scikit-fuzzy, matplotlib, Pillow, and tinter. The code includes modules for data preprocessing, fuzzy membership and rule definition, inference computation, and a graphical user interface for prediction

and visualization. The source code can be made available by the corresponding author upon reasonable request.

Author contribution: All authors contributed equally to the conception, design, analysis, and writing of this research paper.

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Applications of Partial Differential Equations in Deep Learning and Artificial Intelligence

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Abstract

Artificial Intelligence (AI) has been growing rapidly because of the development of machine learning, optimization methods, and computational mathematics. Partial Differential Equations (PDEs) are some of the mathematical tools that are used in the model of complex dynamic systems. PDEs have found many applications in image processing, computer vision, deep learning optimization, physics-informed neural networks, and reinforcement learning. The equations are a description of the correlation of various factors and their rates of variation, which allows time series modeling of continuous systems and spatial-temporal processes. The paper will discuss the use and purpose of PDEs in Artificial Intelligence, specifically in Image smoothing, edge detection, neural network learning, and physics-based learning models. An example of simple numerical example and Python implementation is also provided to explain how concepts of PDE can be used in computational intelligence.

Keywords: Deep Learning, Partial Differential, Intelligence, Optimization, Neural Network

1. Introduction

Artificial Intelligence was transformed to one of the most revolutionary technologies in the 21st century. Healthcare, finance, autonomous vehicles, natural language processing, and numerous other areas are some areas where AI systems are applied. AI success depends on the mathematical basis of linear algebra, calculus, probability theory, optimization, and numerical methods. Partial Differential Equations (PDEs) are some of the mathematical tools that give a formidable system of modeling systems that change with time and place. A Partial Differential Equation is an equation in which a multivariate function is being considered and its partial derivatives are taken. PDEs find extensive

applications in physics and engineering to model such phenomena as diffusion of heat and wave propagation, and fluid mechanics. During recent years, scientists have found that PDEs may be used to model learning both via Artificial Intelligence, feature extractions, and data transformations.

In this paper, the role of PDEs in AI and its application in different fields of AI are examined and illustrated by their practical use.

2. Mathematical Background of Partial Differential Equations

The general equation of Partial Differential Equation is $F(x, y, u, u_x, u_y, u_{xx}, u_{yy}, \dots) = 0$ Where $u = u(x, y)$ is an unknown function u_x, u_y represent first-order partial derivatives of function $u(x, y)$. u_{xx}, u_{yy} represent second-order derivatives of function $u(x, y)$.

3. Applications of PDEs in Artificial Intelligence

3.1 Image Processing and Computer Vision

Image processing is one of the most crucial uses of PDEs in AI. Sensors usually introduce noise in images. Diffusion techniques based on PDE assist in the removal of noise and also conserving the characteristics of the image such as edges.

The heat diffusion equation is commonly used: $\partial I / \partial t = \nabla^2 I$

where $I(x, y, t)$ represents the pixel intensity.

It is an equation that blurs the image of the object at a gradual pace. Other sophisticated models like anisotropic diffusion preserve edges and remove noise. Medical image analysis, satellite imaging, and facial recognition systems are some of the widely used methods of these techniques.

3.2 Edge Detection

One of the tasks in computer vision is edge detection. PDEs are used to find boundaries in images based on the changes in gradient.

Perona–Malik diffusion model is widely used: $\partial I / \partial t = \nabla \cdot (c(x, y, t) \nabla I)$

where $c(x, y, t)$ controls diffusion strength.

3.3 Deep Learning and Neural Network Optimization

Training deep neural networks requires optimization of large parameter spaces. Continuous-time models of neural networks can be described using differential equations.

Gradient descent can be viewed as a discretized version of a differential equation: $d\theta/dt = -\nabla L(\theta)$ where θ represents model parameters and $L(\theta)$ represents the loss function.

Neural networks in deep learning studies are also sometimes modelled as PDEs to learn more about learning dynamics and stability.

4. Numerical Example

Consider the heat diffusion equation used for smoothing data. $\partial u / \partial t = \partial^2 u / \partial x^2$
Using finite difference approximation: $u_{it+1} = u_{it} + \alpha(u_{i+1t} - 2u_{it} + u_{i-1t})$

Suppose initial values are:

x	u(x,0)
0.0	5.00
1.0	10.00
2.0	8.00
3.0	6.00
4.0	4.00

After one iteration the updated values become smoother, demonstrating diffusion behaviour.

This principle is used in AI algorithms for noise reduction and feature smoothing.

5. Python Implementation

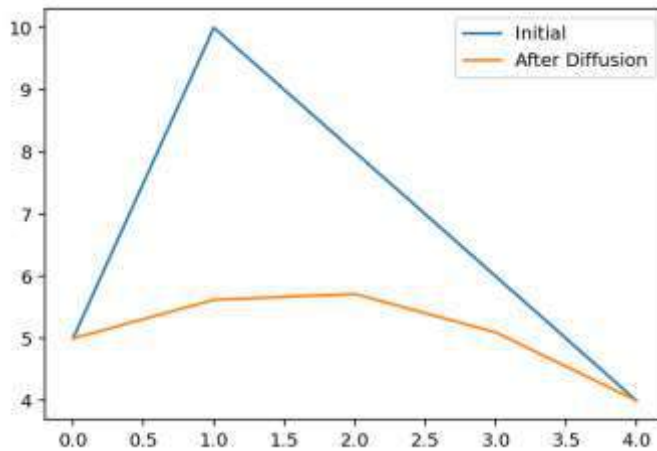
The following Python program demonstrates a simple diffusion process based on the heat equation.

```
import numpy as np # include numerical python
import matplotlib.pyplot as plt # matplotlib library for plotting
u = np.array([5.0,10.0,8.0,6.0,4.0], dtype=float)
alpha = 0.2 # learning steps
n = len(u) #length of array
def diffusion(u,steps): # define function
    for t in range(steps): # loop for iteration
        u_new = u.copy() # declared variable
        for i in range(1,n-1): # for loop for iteration
            u_new[i] = u[i] + alpha*(u[i+1]-2*u[i]+u[i-1])
        u = u_new
    return u # return the value to function
result = diffusion(u,10)
print("Initial values:",u) # display the output
print("Smoothed values:",result)
```

```
plt.plot(u,label="Initial") # plot the given graph  
plt.plot(result,label="After Diffusion") # title of given graph  
plt.legend() # plot the information  
plt.show() # to display the plot
```

The program simulates the diffusion process that smooths data values over iterations. Similar approaches are used in AI for image filtering and feature extraction.

Output Obtained:



6. Results and Discussion

The smoothing property of diffusion equations is shown by the numerical example and Python simulation. The irregular variations were found in the first data but with repetitive iterations the values would get smoother and stable.

Such smoothing methods are useful in AI applications to reduce noise in data, enhance feature extraction and model performance. PDE-based algorithms are especially useful in computer vision applications like image denoising, image segmentation and edge detection.

Moreover, the combination of PDEs and neural networks has given rise to such new research directions as Physics-Informed Neural Networks and Neural Differential Equations. These methods are a mix of old-fashioned mathematical modeling and the new method of machine learning.

PDE-based models are also more interpretable in AI systems as they include physical laws and mathematical principles that are known. This allows them to be applied in scientific AI like climate prediction, medical diagnostics and engineering simulations.

Nonetheless, the computational cost of obtaining numerical solutions to high dimensional PDEs can be very high. Hence, there is a need of efficient algorithms and hybrid techniques that include the numeric methods and machine learning.

7. Conclusion

Artificial Intelligence techniques often have good mathematical roots in Partial Differential Equations. They allow the simulation of spatial-temporal processes and continuous systems, which are found in real life data. PDEs have been applied in image processing, deep learning optimization, reinforcement learning, and physics-informed neural networks.

Application of PDEs in machine learning has created new research possibilities in scientific computing and data-driven modelling. With the ever-expanding computational power, AI models based on the PDEs will be the more significant in tackling complex real-world problems.

The future studies can be dedicated to the creation of hybrid models, that is, the models that integrate both the PDE theory with deep learning networks to enhance the accuracy, interpretability, and efficiency of AI systems.

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Applications of Science and Technology in Artificial Intelligence and Machine Learning

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Abstract

Artificial intelligence and machine learning (AI/ML) algorithms are not only the most rapidly expanding fields but offer limitless opportunities in most various fields of science and engineering including computer communication networks. Billions of people use these technologies. Any individual with a smartphone can actually feel the benefits of the improvements in communication networks, social media, natural language processing and computer vision that were not present only 10 years ago. It is thus necessary to carry out research in order to comprehend and enhance the potential and appropriateness of AI/ML, generally, in communications and networking technologies but, specifically, in systems and networks operations and management. The world is changing based on Artificial Intelligence (AI) and Machine Learning (ML). AI can be defined as the art of simulating human intelligence in machines and ML is a subfield of AI where systems are able to learn through data and become better in their tasks without having to be explicitly programmed. The paper highlights the meaning of AI and ML, the development, methods, uses, benefits, difficulties, and prospective of the same. Ethical issues and the responsible implementation are also discussed in the course of the study.

1. Introduction

One of the most radical technologies in the 21st century is Artificial Intelligence. John McCarthy was the first scholar to give a formal introduction of the notion of AI in 1956. The goal of AI is to develop systems that can execute jobs that are traditionally performed by humans through intelligence like reasoning, learning, decision-making, language perception and problem solving.

Machine Learning is a subdivision of AI and is concerned with the creation of algorithms that enable computers to learn data and apply them to

make predictions or decisions without providing explicit instructions, which can be explained as learning by doing.

Artificial Intelligence (AI) is a branch of computer science that deals with the development of machines with capability to execute tasks that will otherwise need human intelligence, including reasoning, problem-solving, and learning. Machine Learning (ML) is a particularly narrow branch of AI, which allows systems to learn based on the available information and become more effective with time, without being explicitly programmed to act in a particular scenario.

2. Objectives of the Study

- To learn the idea and development of Artificial Intelligence.
- To examine various forms of Machine Learning methods.
- To investigate the practical use of AI and ML.
- To determine challenges and ethical problems.
- To dwell upon the perspective of AI and ML.

3. Idea of Artificial Intelligence.

Artificial Intelligence is a term used to describe the machines that are supposed to think, learn and behave as humans. AI systems can perform:

- Speech recognition
- Image processing
- Decision-making
- Understanding natural language.
- Robotics

4. Categories of Artificial Intelligence.

4.1 Narrow AI (Weak AI) - It is created to perform specific tasks (e.g., voice assistants). The interface is created to carry out only one particular activity (e.g., Siri, Netflix recommendations, or spam filters). It is the only form of AI that exists.

4.2 General AI (Strong AI) - Intelligence of a human level (theoretical). A hypothetical machine that is able to do any intellectual job that a human can do such as reasoning and adjusting to new circumstances without the need to re-program.

4.3 Super AI - Where the human level of intelligence is surpassed (hypothetical). A hypothetical stage in which AI is more intelligent than human in every sphere, including social and creative ability.

4.5 Based on Functionality

This method according to researcher Arend Hintze emphasizes on the way a system processes information and also its interaction with the world.

4.6 Reactive Machines: The simplest type; they can react to immediate signals, but cannot retain memories, and cannot learn experience (e.g. the chess computer Deep Blue by IBM).

Limited Memory: Is able to utilize past data in order to make improved decisions. The majority of the current AI, such as self-driving cars and chatbots, can fall into this category.

Theory of mind: This is a theoretical form that might describe human feelings, beliefs and desires to interact in a natural manner.

Self-Awareness: The last frontier When AI has its own awareness, self-identity and internal drive. This is purely hypothetical.

4.7 Machine Learning: Definition and Classifications.

Machine Learning allows computers to learn what to do on past data and get better as time goes.

4.8 Supervised Learning

The model is trained with some labeled data, i.e. it is given an answer key (input/output pairs). It gets to learn how to get to given correct outputs on inputs.

Subtypes: Classification (e.g., what is spam and what is not spam) and Regression (e.g., what are the prices of houses).

4.9 Unsupervised Learning

The model operates on unlabeled data. It recognizes internal groupings, structures, or patterns without being directed by someone.

Types: Clustering (e.g., clustering customers based on behavior) and Association (e.g., customers who purchased this also purchased that).

4.10 Reinforcement Learning

A learning agent is the one that learns through experience, through interaction with an environment. It is rewarded in its good actions and penalized in its bad actions in order to maximize its overall score.

5. Applications of AI and ML

Healthcare

- Disease prediction
- Medical image analysis
- Drug discovery

Finance

- Fraud detection

Credit scoring
Algorithmic trading

Education

Smart tutoring systems
Automated grading

Business and Marketing

Customer behavior analysis
Recommendation systems

E-commerce

Businesses such as Amazon apply AI in their product suggestions and optimization of the supply chain.

Transportation

Tesla created self-driving technology that is based on AI and ML algorithms and provides autonomous driving.

6. Advantages of AI and ML

- Increased efficiency
- Faster decision-making
- Reduction in human error
- 24/7 availability
- Repetitive tasks are automated.

7. Challenges and Limitations

And now we must be realistic, AI is not that strong, nor flawless.

High implementation cost

Data privacy concerns

Job displacement risks

Bias in algorithms

Absence of transparency (Black box problem)

The uncontrolled introduction of AI may cause severe ethical and social issues.

Ethical Issues in AI

- Data misuse
- Surveillance concerns
- Algorithmic bias
- Accountability issues

Good governance structures should be in place to have responsible forms of AI development.

Future Scope of AI and ML

The future of AI includes:

- Advanced robotics
- Smart cities
- AI-powered healthcare
- Quantum machine learning

Human-AI collaboration

Nevertheless, the future will rely on the responsible innovation, the ethical principles, and the adequate regulation.

8. Conclusion

AI and ML are changing the present-day world. On the one hand, they provide a profoundly beneficial effect in the realm of automation, efficiency, and innovation, on the other, there are some issues of ethics, employment, and privacy. It is important not to blindly foster AI but to combine technological progress with responsible management. Governments, organizations and researchers should collaborate to make sure that AI works in the best interest of the entire humanity.

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Applications Of Numerical Techniques in Machine Learning and Artificial Intelligence

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Abstract

Artificial Intelligence (AI) is one of the newest technologies that have become a key driver of modern computing and is used in image recognition, natural language processing, autonomous vehicles, and healthcare analytics. These intelligent systems are backed up by a solid mathematical basis especially by numerical techniques. Numerical Methods give efficient procedures in solving mathematical problems that are not solvable analytically or they demand approximations of computation. They are important in the training of machine learning models, algorithm optimization, solving of DEs, and the processing of large data volumes. This paper will discuss the uses and purposes of numerical methods in artificial intelligence, such as optimization, matrix computations, root-finding methods, numerical differentiation and numerical integration. The paper emphasizes the role of numerical algorithms to improve the efficiency and accuracy of AI systems and explains the uses of the tool in the fields of neural networks, computer vision, and predictive analytics.

Keywords: Artificial Intelligence, Numerical Methods, Optimization, Machine Learning, Gradient Descent, Computational Mathematics

1. Introduction

Artificial Intelligence (AI) is the concept of having machines undertake tasks that are normally considered to be carried out by humans, including reasoning, learning, the decision-making process, and the recognition of patterns. The contemporary AI systems are extensively dependent on mathematical models and computational methods to work with data and provide meaningful information. Among them, the number of methods is an essential part of solving complicated mathematical problems that are presented in AI.

Numerical methods are mathematical algorithms that are applied to approximate solutions to problems that do not necessarily have analytical solutions. They are especially useful in the case of large data, nonlinear equations, and high-dimensional optimization problems that are typical of AI applications.

The growing complexity of AI models has led to choosing numerical computations as the only way to implement it efficiently. In this paper, the significant numerical approaches in AI and the way they are applied in various fields will be discussed.

2. Numerical Methods in Artificial Intelligence

The numerical techniques involve a host of computational methods that comprise iterative methods, approximation, and optimization methods.

In some fundamental ways, some of the numeric techniques employed in AI include:

- Optimization Methods
- Numerical Linear Algebra
- Root-Finding Algorithms
- Numerical Differentiation
- Numerical Integration
- Iterative Techniques of Large Systems.

Most AI methods are mathematically supported by these approaches.

3. Gradient Descent

Gradient descent is a mathematical optimization model that is applied in minimizing loss functions within machine learning models. It operates by changing the model parameters by moving them through the negative gradient.

Mathematically, $\theta_{new} = \theta_{old} - \alpha \nabla J(\theta)$ where θ = model parameters and α = learning rate

$J(\theta)$ = cost function

Gradient descent is widely used in:

- Linear regression
- Neural networks
- Deep learning models
- Logistic regression

4. Numerical Linear Algebra in AI

Majority of AI algorithms are very dependent on matrices operations. These operations are efficiently performed with the assistance of numerical linear algebra methods.

Key techniques include: Matrix Multiplication, Applied in neural networks in forward propagation, Eigenvalue Computation Significant in methods of dimensionality reduction like Principal Component Analysis (PCA). Singular Value Decomposition (SVD) Used in: Recommendation systems, Image compression NLP Natural language processing.

5. Root-Finding Methods in AI

The nonlinear equations that are solved to find the roots are used in optimization problems. Examples of some common numerical methods of finding roots are: Newton-Raphson Method, Bisection Method, Secant Method Considering the example of the Newton-Raphson method the values are updated as follows.

$$: x_{n+1} = x_n - f(x_n)/f'(x_n)$$

Such methods are applied in AI applications in: Estimation of the parameter of logistic regression. Probabilistic model training., Nonlinear optimization Solving problems.

6. Numerical Differentiation in Deep Learning

Deep learning models involve the derivation of loss functions with respect to the parameters of a model. When the derivatives are not easy to calculate, numerical differentiation assists in the approximation of the derivatives.

One common approximation is the finite difference method: $f'(x) \approx f(x + h) - f(x) / h$

Applications include: Differentiation in neural networks., Gradient-based optimization, Algorithms of reinforcement learning.

7. Numerical Integration in AI

Numerical integration is applied when it is hard or impossible to compute integrals analytically.

Common techniques include: Trapezoidal Rule, Simpson's Rule, Monte Carlo Integration, In AI, Monte Carlo methods have been applied to: Bayesian inference, Reinforcement learning

Probabilistic models

In a Bayesian machine learning example, numerical integration for probability distribution integrals is frequently used.

8. Applications of Numerical Methods in AI Systems

8.1 Neural Networks

The optimization of neural networks requires the modification of millions of parameters through numerical optimization algorithms, like the gradient descent.

Numerical procedures are applied to: Weight updates, Loss minimization, Backpropagation

8.2 Computer Vision

Image processing algorithms are based on the numerical operations like matrix transformations, convolution operations, and optimization.

Applications include: Object detection, Face recognition, Image classification

8.3 Natural Language Processing

Natural Language Processing (NL) represents an additional software development field that offers opportunities to observe more effectively how companies could use AI in their operations. NLP Natural language processing (NLP) is another area of software development, which provides a chance to see better how companies might apply AI to their business.

Applications include: Word embeddings, Language translation, Chatbots

8.4 Autonomous Vehicles

The self-driving cars apply numerical algorithms to:

Sensor data processing, Path optimization, Real-time decision making

Motion planning involves the use of optimization and numerical different equations.

8.5 The medical and healthcare

The medical and healthcare diagnosis field is highly sensitive and requires analysis by lawyers who are proficient in this domain. Medical and healthcare diagnosis 8.5 is a very sensitive area and it needs to be analyzed by lawyers who have been specialized in this area.

9. Numerical Example: Gradient Descent for Linear Regression

Consider a dataset with input x and output y . The linear regression model is:
 $y = mx + c$

The cost function is $J(m, c) = \frac{1}{n} \sum (y_i - (m x_i + c))^2$

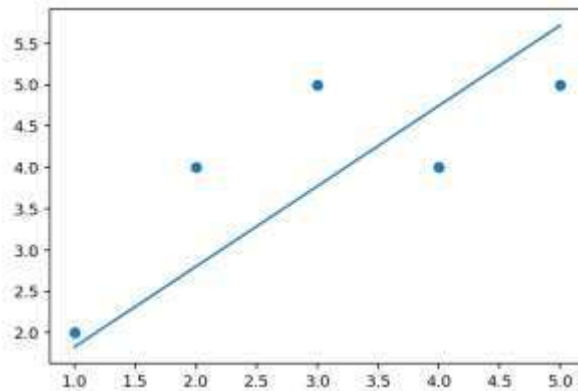
Gradient descent updates parameters iteratively.

9.1 Python Implementation

```
import numpy as np #numerical python library
import matplotlib.pyplot as plt # plotting library
x = np.array([1.0,2.0,3.0,4.0,5.0])
y = np.array([2.0,4.0,5.0,4.0,5.0])
m = 0.0
c = 0.0
lr = 0.01
epochs = 100.0
```

```
n = len(x)
for i in range(epochs):
    y_pred = m*x + c
    dm = (-2/n)*sum(x*(y - y_pred))
    dc = (-2/n)*sum(y - y_pred)
    m = m - lr*dm
    c = c - lr*dc
print("Slope:",m) # display slope
print("Intercept:",c) # display intercept
plt.scatter(x,y) #plot scatter
plt.plot(x,m*x+c) #plot predicted values
plt.show() # display plot
```

This program demonstrates how numerical optimization helps train a machine learning model.



10. Advantages of Numerical Methods in AI

- Complex mathematical problem enable solutions.
- Big data efficient.
- Both conditions are necessary in machine learning.
- Enhance AI with real-time calculation.
- Scalable deep learning models.

Challenges

- Irrespective of their significance, numerical techniques have a number of problems:
- Computer cost of large models.
- Numerical instability
- Convergence issues
- Parameters sensitivity.

Researchers are constantly coming up with better numerical algorithms to

overcome such problems.

12. Conclusion

Artificial intelligence systems are developed and implemented with the help of numerical methods. They offer effective computational aids to solve optimization problems, carry out matrix maths, estimate derivatives and integrate complicated mathematical models. Gradient descent, numerical linear algebra, and Monte Carlo techniques are common in contemporary machine learning and deep learning programs.

With the further development of AI models, numerical methods will become even more important. The developments of numerical algorithms will allow training it faster, more closely, and work with the large data volumes more effectively. It is probable that the future research will be aimed at creating more stable, scalable, and efficient numerical methods to underpin next-generation AI systems.

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The Role of Data Science and Big Data Analytics in Modern Digital Transformation

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Abstract

In the digital age, organizations are producing vast amount of data at a number of different sources including social media, sensors, financial transactions and mobile devices. Such large and complicated datasets cannot be handled effectively using the traditional data processing systems. Big Data Analytics and Data Science have become the highly potent technologies that help organizations to derive meaningful information and facilitate the process of decision-making. Data science is a field that involves the combination of statistics, machine learning, data mining, and programming to handle structured and unstructured data. Big Data Analytics is concerned with the processing of very large volumes of data with the help of sophisticated tools and distributed computing systems. The present research paper examines the idea of data science and big data analytics, its features, technologies, uses, and issues. It also brings out the way in which the organizations apply these technologies in enhancing their operational efficiency, and forecasting future trends as well as competitive advantages. The research makes a conclusion that data science and big data analytics can change the industries through the implementation of the two practices of data-driven decision-making and innovation.

Keywords: Data Science, Big Data Analytics, Machine Learning, Data Mining, Hadoop, Predictive Analytics, Artificial Intelligence, Data Processing.

1 Introduction:

As a result of the trajectory of the booming development of digital technologies, the volume of data generated worldwide has grown exponentially. Online transactions, social networks, IoT devices, and enterprise applications help businesses, governments, and people to produce huge amounts of data on a daily

basis. It has proved to be more difficult to manage and analyze this data using an old system of database.

The emergence of data science and big data analytics has become an important technology that assists organisations to handle and analyze vast amounts of data effectively. Data science is a discipline that centers around deriving a knowledge and insights out of data through the use of statistical analysis, machine learning, and programming. Big data analytics is the term used to describe the process of analyzing large and complex data in order to identify patterns, correlations and trends.

These two technologies when combined help organizations to obtain valuable information and insights with data which will help them make better decisions, provide better customer experiences and optimize business processes.

2. Concept of Data Science

Data science is an interdisciplinary profession which entails application of scientific methodologies, algorithms, and systems to analyze and draw valuable insights out of the data. It is a combination of statistical, mathematical, computer science, and domain knowledge.

Data science is primarily aimed at transforming raw data into valuable information that can be used to make decisions. Python, R, and SQL are some of the programming languages that data scientists use to analyze and visualize data.

2.1 Key Components of Data Science

- **Data Collection:** Sources of data are databases, sensors, web sites and mobile apps.
- **Data Cleaning:** Raw data usually has some mistake, missing values or inconsistency. Data cleaning will make the data set accurate and of quality.
- **Data Analysis:** Data is analyzed by use of statistical methods and machine learning algorithms to identify patterns.
- **Data Visualization:** Insights are presented and displayed in the form of graphs, charts, and dashboards to make sense.
- **Decision Making:** Strategic decisions are made by organizations based on information garnered during data analysis.

2.2 Big Data Analytics concept:

This is a conceptual framework that describes how to analyze large datasets to derive insightful conclusions about the organizations or events being analyzed.

<|human|>3. Concept of Big Data Analytics This is a theoretical construct that

explains the process of analysing large amounts of data to come up with an insightful conclusion about the organisations or events under analysis.

Big Data is the term applied to extremely large and complicated datasets that cannot be processed through the traditional data processing tools. Big Data Analytics is the process of extracting the concealed patterns, correlations and insights of these datasets.

The most common descriptions of big data use the 5V features:

- Volume - Large quantities of data in a daily basis.
- Velocity - Rate of data generation and process.
- Variety - Data of various types including structured, semi-structured and unstructured.
- Veracity- Accuracy and reliability of data.
- Value - Valueable data mined.

3. Technologies in the Big Data Analytics.

3.1 Hadoop

Hadoop is a framework that is open-source and is used in storing and processing of large datasets over distributed computing clusters. It stores data in Hadoop Distributed File System (HDFS).

3.2 Apache Spark

Apache Spark is a high-speed data processing engine that comes up with large-scale data analytics through in-memory computation.

3.3 NoSQL Databases

No SQL databases like MongoDB and Cassandra are made to efficiently store semi-structured and unstructured data.

3.4 Machine Learning

Machine learning algorithms are used to determine trends and predictions which are based on previous data.

3.5 Data Visualization Tools

Tableau and Power BI are tools that are used to visualise complex data that can be understood and made decisions.

4. Data Science and Big Data Analytics in Applications.

4.1 Healthcare

Big data analytics and data science contribute to the analysis of patient records, prediction of disease outbreaks, and better treatment. Predictive analytics is applied in hospitals to identify diseases at the initial stage.

4.2 Finance

Fraud detection, risk management, and algorithmic trading are the areas that financial institutions apply big data analytics. It assists banks in detecting suspicious activities and averting financial offenses.

4.3 Retail

The retail firms study the buying habits of customers in order to enhance product preferences and advertising.

4.4 Transportation

Traffic management, optimization of logistics operations and less fuel consumption are optimized with the help of big data analytics.

4.5 Social Media Analysis

Firms utilize the data sent through social media in order to get a feel of what people think, how they feel about their products and services and the reputation of the brands.

Data Science and Big Data Analytics Advantages.

4.6 Improved Decision Making

Organizations are able to make decisions which are informed by the precise information.

4.7 Better Customer Experience

Businesses are able to learn the customer behavior and customize services.

4.8 Operational Efficiency

Analytics assists in streamlining of processes and minimizing costs of operation.

4.9 Predictive Analysis

Predictive models help companies to estimate the future and realize the trends.

4.10 Competitive Advantage

Companies that employ data analytics successfully have an upper hand over their rivals.

4.11 Issues of Big Data Analytics.

Big data analytics has a number of challenges although it has benefits.

4.12 Data Privacy and Security

Managing high volumes of sensitive information heightens data breach and cyber-attacks.

4.13 Data Quality Issues

The data of low quality may result in incorrect analysis and wrongful conclusions.

4.14 High Infrastructure Cost

The installation of big data infrastructure is costly regarding hardware, software, and professional talent.

4.16 Skill Gap

The need of skilled data scientists and big data engineers that are capable of sifting through complex data is on the increase.

5. Future Scope

The future of the data science and big data analytics is highly promising. Artificial intelligence, deep learning, and the Internet of Things (IoT) are emerging technologies that will only add more and more data to the volume and complexity of data. Organizations will turn more to the use of advanced analytics to draw insights and automate the decision-making process. Big data technologies are becoming more accessible and achievable through cloud computing which includes AWS, Google Cloud, and Microsoft Azure. In the next few years, solid data science and big data analytics will be a crucial part of digital transformation in the sphere of industries.

6. Conclusion

In the contemporary digitalized economy, data science and big data analytics have been indispensable to organizations. The technologies can allow companies to handle large amounts of data and derive valuable insights that can be used in making strategic decisions. Through integration of statistical analysis, machine learning and distributed computing models, companies can efficiently analyze multifaceted data. Despite the difficulties to privacy of the data, the expenses of the infrastructure and the lack of skilled personnel, the advantages of big data analytics are more significant than the restrictions. The role of data science and big data analytics is set to expand greatly as data keeps increasing in a very quick manner. Companies that successfully embrace these technologies will have a competitive edge and become innovative in future.

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Predictive Modeling of Nominal Gross Domestic Product (Gdp) in Current USD For India (2025-2030) Using Regression Training Analysis and Machine Learning

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Abstract

This research focuses on the analysis of India's Nominal Gross Domestic Product (GDP) from 1993 to 2022, utilizing online data sources. Employing linear regression models in Python programming, the study seeks to unravel patterns and trends within the historical GDP Nominal (Current USD) data. The trained models are then leveraged to predict future trends in Nominal GDP, providing a valuable tool for understanding and forecasting economic trajectories. This research contributes to the broader goal of fostering sustainable socio-economic growth for a self-reliant Bharat.

Keywords: GDP, Machine Learning, Linear Regression, Python Programming.

1. Introduction

In the pursuit of understanding and unraveling the economic trajectory of India, this research focuses exclusively on the Nominal Gross Domestic Product (GDP) from 1993 to 2022. Nominal GDP, represented in current USD, serves as a pivotal economic indicator, reflecting the total market value of goods and services produced within the country. Through a meticulous examination of historical data and the application of linear regression models in Python programming, this study aims to discern patterns and trends specific to Nominal GDP. By concentrating landscape of India, paving the way for informed decision-making and sustainable socio-economic growth on this key economic parameter, we seek to contribute valuable insights into the financial.

2. Methodology

We initiated the study by constructing a comprehensive table encompassing Nominal Gross Domestic Product (GDP) in current USD, specifically focusing on data from the years 1993 to 2022.

Table 1: Gross Domestic Product (GDP) of India

Year	GDP Nominal (Current USD)	Year	GDP Nominal (Current USD)
2022	\$3,385,090,000,000	2000	\$468,395,000,000
2021	\$3,150,310,000,000	1999	\$458,820,000,000
2020	\$2,671,600,000,000	1998	\$421,351,000,000
2019	\$2,835,610,000,000	1997	\$415,868,000,000
2018	\$2,702,930,000,000	1996	\$392,897,000,000
2017	\$2,651,470,000,000	1995	\$360,282,000,000
2016	\$2,294,800,000,000	1994	\$327,276,000,000
2015	\$2,103,590,000,000	1993	\$279,296,000,000
2014	\$2,039,130,000,000	Machine Learning: Training Models using Linear Regression In python Programming.	
2013	\$1,856,720,000,000	<i>Python Program:</i>	
2012	\$1,827,640,000,000	<i>import pandas as pd</i>	
2011	\$1,823,050,000,000	<i>import numpy as np</i>	
2010	\$1,675,620,000,000	<i>import matplotlib.pyplot as plt</i>	
2009	\$1,341,890,000,000	<i>df=pd.read_csv("gdp.csv")</i>	
2008	\$1,198,900,000,000	<i>x=df.iloc[:,0], y=df.iloc[:,1]</i>	
2007	\$1,216,740,000,000	<i>x=np.array(x),y=np.array(y)</i>	
2006	\$940,260,000,000	<i>from sklearn.linear_model import</i>	
2005	\$820,382,000,000	<i>LinearRegression</i>	
2004	\$709,149,000,000	<i>linreg=LinearRegression()</i>	
2003	\$607,699,000,000	<i>x=x.reshape(-1,1),plt.plot(x,y,".")</i>	
2002	\$514,938,000,000	<i>plt.title("GDP Nominal")</i>	
2001	\$485,441,000,000	<i>linreg.fit(x,y)</i>	
		<i>xnew=np.array([[0],[2030]])</i>	
		<i>print(linreg.predict(xnew))</i>	
		<i>ypred=linreg.predict(x)</i>	
		<i>plt.plot(x,ypred,".r"),plt.show()</i>	

3. Result

Our analysis, employing regression training analysis and machine learning through Python programming, yields predicted values for Nominal Gross Domestic Product (GDP) in current USD for the years 2025 to 2030.

Table 2: Future predicted values using Machine Learning Regression Analysis.

2030	\$3,744,163,344,827
2029	\$3,639,232,689,655
2028	\$3,534,302,034,482
2027	\$3,429,371,379,310
2026	\$3,324,440,724,137
2025	\$3,219,510,068,965

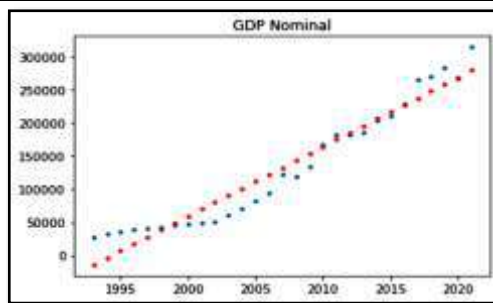


Figure 1: Linear Regression

4. Conclusions

In conclusion, our study on Nominal Gross Domestic Product (GDP) using regression training analysis and machine learning provides a valuable forecast for the years 2025 to 2030. By focusing solely on Nominal GDP in current USD, we offer insights into the expected economic trends, aiding stakeholders and policymakers in making informed decisions for sustained growth and prosperity in India. This targeted analysis contributes to a more nuanced understanding of the financial landscape, emphasizing the significance of Nominal GDP in shaping the nation's economic future.

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Geometric Properties of a Certain Subclass of p-Valent Functions

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Abstract

In this study, we define a novel subclass of p-valent analytic functions in the open unit disk $D = \{z: z \in \mathbb{C}, |z| < 1\}$. Within the framework of geometric function theory, fundamental properties of this class are investigated. In particular, we derive coefficient estimates for functions belonging to the proposed class and analyze the behaviour of their partial sums. Furthermore, results associated with the modified Hadamard product (convolution) are established. The obtained results provide new insights into the geometric structure of the considered subclass and extend some existing results for p-valent functions.

2020 Mathematics Subject Classification: 30C45.

Keywords: Analytic function, Coefficient Estimate, Hadamard Product.

1. Introduction

A significant area of complex analysis is known as "Geometric Function Theory," which examines the geometric behavior of analytic functions in the unit disk. In order to comprehend different geometric aspects, including growth, distortion, coefficient estimations, and convolution structures, several subclasses of analytic and multivalent functions have been created and investigated throughout the years. These investigations play an important role in developing a deeper understanding of the analytic and geometric nature of complex functions.

If a function f , analytic on the unit disk D , takes each value exactly p times in D ,

counting multiplicities, it is considered p-valent. Due to its complex mathematical structure and applications in geometric function theory, the theory of p-valent functions—a natural extension of the classical theory of univalent functions—has gained considerable interest.

Many researchers have studied different subclasses of p-valent functions and obtained results related to coefficient estimates, inclusion relationships, and convolution properties. Inspired by these developments, we provide a novel subclass of p-valent analytic functions defined on the open unit disk in this study. Studying certain geometric characteristics related to this class is the main goal of this research. Specifically, we derive coefficient bounds for functions in the suggested class and analyze how their partial sums behave. Results about the modified Hadamard product (convolution) are also established. These findings expand on certain known findings in the theory of p-valent functions and help to clarify the geometric structure of the proposed subclass.

2. Preliminaries

We consider the class \mathcal{A} of analytic functions l of the form defined on the unit disc $D = \{z: z \in \mathbb{C}, |z| < 1\}$ having the series expansion

$$l(z) = z + \sum_{m=2}^{\infty} d_m z^m. \tag{1}$$

We define \mathcal{T} as a subclass of \mathcal{A} whose elements are functions l represented by

$$l(z) = z + \sum_{m=2}^{\infty} d_m z^m, \quad (d_m \geq 0). \tag{2}$$

Silverman was the first to define and examine this subclass [12].

Let $\mathcal{A}(p)$ denote the class of analytic p-valent functions l defined on the unit disc $D = \{z: z \in \mathbb{C}, |z| < 1\}$, having the representation

$$l(z) = z^p + \sum_{m=1}^{\infty} d_{m+p} z^{m+p}, \quad p \in \mathbb{N} = \{1,2,3, \dots\} \tag{3}$$

Let $\mathcal{T}(p)$ be the denote the family of functions in $\mathcal{A}(p)$ having the series expansion

$$l(z) = z^p - \sum_{m=1}^{\infty} |d_{m+p}| z^{m+p}. \tag{4}$$

The subclass of analytic functions given below was defined by F. Ghanim in [5].

Definition 1. The function l given by (1.1) is said to be a member of the class $\mathcal{M}(\alpha, \beta, \gamma, A, \lambda)$ if it satisfies $\left| \frac{zl'(z)-l(z)}{\alpha zl'(z)-Al(z)-(1-A)(1-\lambda)\gamma l(z)} \right| < \beta$, where $0 \leq \alpha \leq 1$, $0 < \beta \leq 1$, $-1 \leq A < 1$, $0 \leq \gamma < 1$, $0 \leq \lambda \leq 1$ for all $z \in D$.

Darus [4] explored the class of functions for $A = -1$ and $\lambda = 1/2$. Kim and Lee [7], Uralegaddi and Sarangi [16], and Al-Amiri [3] have all examined the class of $L^*(\alpha)$ and several additional subclasses of L^* that result from substituting $\frac{zl'(z)}{l(z)}$ with $zl'(z)$ under the identical conditions. Silverman [12] provided the class of functions if $\lambda = 0$, $\beta = 1$ and $A = -1$. Ma'moun Al-Harayzeh Al-Abbadi presented some intriguing subordination results for $\mathcal{M}(\alpha, \beta, \gamma, A, \lambda)$ in [2].

A new subclass $M(\alpha, \beta, \gamma, A, \lambda, p)$ including analytic and multivalent functions was established by F. Ghanim and M. Darus in [6].

Definition 2. Let a function l given by $l(z) = z^p + \sum_{m=2}^{\infty} d_{m+p} z^{m+p}$, ($p \in \mathbb{N}$) in the class $\mathcal{M}(\alpha, \beta, \gamma, A, \lambda, p)$ if it satisfies $\left| \frac{zl'(z)-pl(z)}{\alpha zl'(z)-Apl(z)-(1-A)(1-\lambda)\gamma l(z)} \right| < \beta$, where $0 \leq \alpha \leq 1$, $0 < \beta \leq 1$, $-1 \leq A < 1$, $0 \leq \gamma < 1$, $0 \leq \lambda \leq 1$ for all $z \in D$ and $p \in \mathbb{N}$.

Setting $A = 0$ and $\alpha = 1$ in Definition 2 we define the new subclass $\mathcal{N}(\gamma, \lambda, \beta, p)$ as follows:

Definition 3. The function l given by (1.3) is said to be in the class $\mathcal{N}(\gamma, \lambda, \beta, p)$ if it satisfies $\left| \frac{zl'(z)-pl(z)}{zl'(z)-(1-\lambda)\gamma l(z)} \right| < \beta$, where $0 < \beta \leq 1$, $0 \leq \lambda < 1$, $0 \leq \gamma < 1$ for all z in D and $p \in \mathbb{N}$.

Define $\mathcal{N}^*(\gamma, \lambda, \beta, p)$ as $\mathcal{N}^*(\gamma, \lambda, \beta, p) = T \cap \mathcal{N}(\gamma, \lambda, \beta, p)$.

Coefficient limits for the classes $\mathcal{N}(\gamma, \lambda, \beta, p)$ and $\mathcal{N}^*(\gamma, \lambda, \beta, p)$ will be found. The objective of this paper is to give partial sums, and the modified Hadamard product of functions in the class $\mathcal{N}^*(\gamma, \lambda, \beta, p)$.

3. Main Results

Theorem 1. The function $l(z)$ of the form (3) satisfies

$$\sum_{m=1}^{\infty} (m + \beta(m + p - (1 - \lambda)\gamma)) |d_{m+p}| \leq \beta(p - (1 - \lambda)\gamma), \quad (5)$$

where $0 < \beta \leq 1$, $0 \leq \lambda < 1$, $0 \leq \gamma < 1$ then $l(z) \in \mathcal{N}(\gamma, \lambda, \beta, p)$.

Proof. Suppose $l \in A(p)$ satisfies given condition. We have to show that $l(z) \in$

$\mathcal{N}(\gamma, \lambda, \beta, p)$. That is

$$\left| \frac{zl'(z) - pl(z)}{zl'(z) - (1-\lambda)\gamma l(z)} \right| < \beta.$$

$$\left| \frac{zl'(z) - pl(z)}{zl'(z) - (1-\lambda)\gamma l(z)} \right| = \left| \frac{\sum_{m=1}^{\infty} (m+p-p)d_{m+p}z^{m+p}}{(p - (1-\lambda)\gamma) + \sum_{m=1}^{\infty} (m+p - (1-\lambda)\gamma)d_{m+p}} \right|$$

$$< \frac{\sum_{m=1}^{\infty} m |d_{m+p}|}{(p - (1-\lambda)\gamma) - \sum_{m=1}^{\infty} (m+p - (1-\lambda)\gamma)|d_{m+p}|}.$$

β is the upper limit of the final expression if

$$\sum_{m=1}^{\infty} m |d_{m+p}| \leq \beta \left[(p - (1-\lambda)\gamma) - \sum_{m=1}^{\infty} (m+p - (1-\lambda)\gamma)|d_{m+p}| \right],$$

which is the same as

$$\sum_{m=1}^{\infty} (m + \beta(m+p - (1-\lambda)\gamma))|d_{m+p}| \leq \beta(p - (1-\lambda)\gamma).$$

Which is given condition in the theorem. \square

Theorem 2. Let the function $l(z)$ of the form (4) then $l(z) \in \mathcal{N}^*(\gamma, \lambda, \beta, p)$ if and only if

$$\sum_{m=1}^{\infty} (m + \beta(m+p - (1-\lambda)\gamma))|d_{m+p}| \leq \beta(p - (1-\lambda)\gamma).$$

Where $0 < \beta \leq 1, 0 \leq \lambda < 1, 0 \leq \gamma < 1$.

Proof. It is enough to show that condition (5) is satisfied if $l(z) \in \mathcal{N}^*(\gamma, \lambda, \beta, p)$.

Suppose that $l(z) \in \mathcal{N}^*(\gamma, \lambda, \beta, p)$. By Definition 3,

$$\left| \frac{zl'(z) - pl(z)}{zl'(z) - (1-\lambda)\gamma l(z)} \right| < \beta.$$

That is

$$\left| \frac{\sum_{m=1}^{\infty} m d_{m+p}z^{m+p}}{(p - (1-\lambda)\gamma) - \sum_{m=1}^{\infty} (m - (1-\lambda)\gamma)d_{m+p}} \right| < \beta.$$

Which gives condition in the theorem. \square

Corollary 1. If the function $l \in \mathcal{N}^*(\gamma, \lambda, \beta, p)$ then $d_{m+p} \leq \frac{\beta(p-(1-\lambda)\gamma)}{(m+\beta(m+p-(1-\lambda)\gamma))} m \geq 1$.

Theorem 3. Under convex linear combination, the class $\mathcal{N}^*(\gamma, \lambda, \beta, p)$ is closed.

Proof. Let $l_1(z) = z^p - \sum_{m=1}^{\infty} d_{m+p,1} z^{m+p}$ and $l_2(z) = z^p - \sum_{m=1}^{\infty} d_{m+p,2} z^{m+p}$ be two functions in the class $\mathcal{N}^*(\gamma, \lambda, \beta, p)$.

The function $k(z) = \mu l_1(z) + (1 - \mu)l_2(z)$, $0 \leq \mu < 1$ need to be shown to be in the class $\mathcal{N}^*(\gamma, \lambda, \beta, p)$.

$$k(z) = z^p - \sum_{m=1}^{\infty} [\mu d_{m+p,1} + (1 - \mu)d_{m+p,2}]z^{m+p}.$$

$l_1(z) \in \mathcal{N}^*(\gamma, \lambda, \beta, p)$ using Theorem 2

$$\sum_{m=1}^{\infty} (m + \beta(m + p - (1 - \lambda)\gamma))|d_{m+p,1}| \leq \beta(p - (1 - \lambda)\gamma).$$

$l_2(z) \in \mathcal{N}^*(\gamma, \lambda, \beta, p)$ using Theorem 2

$$\sum_{m=1}^{\infty} (m + \beta(m + p - (1 - \lambda)\gamma))|d_{m+p,2}| \leq \beta(p - (1 - \lambda)\gamma).$$

Let

$$\begin{aligned} \sum_{m=1}^{\infty} \mu (m + \beta(m + p - (1 - \lambda)\gamma))d_{m+p,1} + \sum_{m=1}^{\infty} (1 - \mu)(m + \beta(m + p - (1 - \lambda)\gamma))d_{m+p,2} \\ \leq \mu\beta(p - (1 - \lambda)\gamma) + (1 - \mu)\beta(p - (1 - \lambda)\gamma) \\ \leq \beta(p - (1 - \lambda)\gamma). \end{aligned}$$

That implies $k(z) \in \mathcal{N}^*(\gamma, \lambda, \beta, p)$. \square

Now, we derive the sharp lower bounds for quotients as follows:

$$\Re \left\{ \frac{l(z)}{l_k(z)} \right\}, \quad \Re \left\{ \frac{l_k(z)}{l(z)} \right\}.$$

To prove theorems in this section we use the following result [13],

$\Re \left\{ \frac{1+p(z)}{1-p(z)} \right\} > 0$, ($z \in D$) if and only if the function $p(z)$ is given by $p(z) = \sum_{m=1}^{\infty} c_m z^m$ satisfies the following inequality: $|p(z)| < |z|$ ($z \in D$).

The function $l(z)$ is expressed as $l(z) = z^p - \sum_{m=1}^{\infty} d_{m+p} z^{m+p}$, and the associated partial sums are given by

$$l_1(z) = z^p, \quad l_k(z) = z^p - \sum_{m=1}^k d_{m+p} z^{m+p} \quad (k \in \mathbb{N}). \quad (6)$$

Theorem 4. Let $l(z) \in \mathcal{N}^*(\gamma, \lambda, \beta, p)$ given by (2) and let its partial sum be given by (6) then

$$\Re \left\{ \frac{l(z)}{l_k(z)} \right\} > 1 - \frac{1}{\sigma_{k+p+1}}, \quad z \in D, \quad (7)$$

and

$$\Re \left\{ \frac{l_k(z)}{l(z)} \right\} > \frac{\sigma_{k+p+1}}{1 + \sigma_{k+p+1}}, \quad z \in D. \quad (8)$$

Where

$$\sigma_{m+p} = \frac{(m+\beta(m+p-(1-\lambda)\gamma))}{\beta(p-(1-\lambda)\gamma)}. \quad (9)$$

Proof. To prove the theorem we use technique used by Silverman [13] and Silvia [14].

The function $l(z) \in \mathcal{N}^*(\gamma, \lambda, \beta, p)$ if and only if $\sum_{m=1}^{\infty} \sigma_{m+p} d_{m+p} \leq 1$.

For the function given by (9) we have $\sigma_{k+p+1} > \sigma_{k+p} > 1$ therefore we get,

$$\sum_{m=1}^k |d_m| + \sigma_{k+p+1} \sum_{m=k+1}^{\infty} |d_m| \leq \sum_{m=1}^{\infty} \sigma_{m+p} |d_{m+p}| \leq 1.$$

Consider

$$\begin{aligned} \frac{1+t(z)}{1-t(z)} &= \sigma_{k+1} \left\{ \frac{l(z)}{l_k(z)} - \left(1 - \frac{1}{\sigma_{k+1}} \right) \right\} \\ &= \frac{1 - \sigma_{k+1} \sum_{m=k+1}^{\infty} d_{m+p} z^m - \sum_{m=1}^k d_{m+p} z^m}{1 - \sum_{m=1}^k d_{m+p} z^m} \\ &= \frac{1+J(z)}{1+K(z)} \end{aligned}$$

which gives

$$t(z) = \frac{J(z) - K(z)}{2 + J(z) + K(z)}$$

, that is

$$t(z) = \frac{-\sigma_{k+1} \sum_{m=k+1}^{\infty} d_{m+p} z^m}{2 - 2 \sum_{m=1}^k d_{m+p} z^m - \sigma_{k+1} \sum_{m=k+1}^{\infty} d_{m+p} z^m}.$$

Now

$$|t(z)| \leq \frac{\sigma_{k+1} \sum_{m=k+1}^{\infty} d_{m+p}}{2 - 2 \sum_{m=1}^k d_{m+p} - \sigma_{k+1} \sum_{m=k+1}^{\infty} d_{m+p}}.$$

$|t(z)| \leq 1$ if and only if

$$2\sigma_{k+1} \sum_{m=k+1}^{\infty} d_{m+p} \leq 2 - 2 \sum_{m=1}^k d_{m+p}.$$

Which is equivalent to

$$\sum_{m=1}^k d_{m+p} + \sigma_{k+1} \sum_{m=k+1}^{\infty} d_{m+p} \leq 1.$$

It is sufficient to show that

$$\sum_{m=1}^k d_{m+p} + \sigma_{k+1} \sum_{m=k+1}^{\infty} d_{m+p} \leq \sum_{m=1}^{\infty} \sigma_m d_{m+p}.$$

Which is e to

$$\sum_{m=1}^k (\sigma_{m+p} - 1)d_{m+p} + \sum_{m=k+1}^{\infty} (\sigma_{m+p} - \sigma_{k+p+1})d_{m+p} \geq 0.$$

This completes the proof of (7).

To prove (8) let us consider

$$\begin{aligned} \frac{1 + q(z)}{1 - q(z)} &= (1 + \sigma_{k+p+1}) \left\{ \frac{l_k(z)}{l(z)} - \frac{\sigma_{k+p+1}}{1 + \sigma_{k+p+1}} \right\} \\ &= \frac{(1 + \sigma_{k+p+1}) \sum_{m=k+1}^{\infty} d_{m+p} z^m - \sum_{m=1}^k d_{m+p} z^m}{1 - \sum_{m=1}^{\infty} d_{m+p} z^m} \end{aligned}$$

where,

$$q(z) = \frac{(1 + \sigma_{k+p+1}) \sum_{m=k+1}^{\infty} d_{m+p} z^m}{2 - 2 \sum_{m=1}^k d_{m+p} z^m + (\sigma_{k+p+1} - 1) \sum_{m=k+1}^{\infty} d_{m+p} z^m}$$

Now,

$$|q(z)| \leq \frac{(1 + \sigma_{k+p+1}) \sum_{m=k+1}^{\infty} d_{m+p}}{2 - 2 \sum_{m=1}^k d_{m+p} z^m - (\sigma_{k+p+1} - 1) \sum_{m=k+1}^{\infty} d_{m+p} z^m}$$

$|q(z)| \leq 1$ if and only if

$$2\sigma_{k+p+1} \sum_{m=k+1}^{\infty} d_{m+1} \leq 2 - 2 \sum_{m=1}^k d_{m+p}$$

which is equivalent to

$$\sum_{m=1}^k d_{m+p} + \sigma_{k+p+1} \sum_{m=k+1}^{\infty} d_{m+p} \leq 1$$

which gives (8). \square

Let the functions $\mathcal{g}(z)$ and $q(z)$ be defined by

$$\mathcal{g}(z) = z^p - \sum_{m=1}^{\infty} c_{m+p} z^{m+p}, \quad q(z) = z^p - \sum_{m=1}^{\infty} e_{m+p} z^{m+p}. \quad (10)$$

The modified Hadaqard product of $\mathcal{g}(z)$ and $q(z)$ is given by

$$(\mathcal{g} * q)(z) = z^p - \sum_{m=1}^{\infty} c_{m+p} e_{m+p} z^{m+p}.$$

Theorem 5. Suppose that functions \mathcal{g} and q from (10) belong to class $\mathcal{N}^*(\gamma, \lambda, \beta, p)$. Then $(\mathcal{g} * q)(z) \in \mathcal{N}^*(\eta, \lambda, \beta, p)$, where $\eta = \frac{1}{1-\lambda} \left\{ p - \frac{(p-(1-\lambda)\gamma)^2 \beta}{\beta+1+2\beta(p-(1-\lambda)\gamma)} \right\}$, $0 < \beta \leq 1$, $0 \leq \lambda < 1$, $0 \leq \gamma < 1$ for all z in D .

Proof. The proof of this theorem can be obtained by applying an approach similar to that used in [1, 11, 15], and hence the details are omitted. \square

4. Conclusion

This chapter presents a novel subclass of p -valent analytic functions that are defined in the open unit disk. Geometric function theory was used to study some important geometric features of this class. In particular, coefficient estimates and the behavior of partial sums were studied. We also obtained results related to the

modified Hadamard product. The results presented here contribute to a better understanding of this class of functions and may encourage further research in this direction.

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Role of Linear Algebra in Modern Artificial Intelligence

Applications

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Abstract

Linear algebra has a central place in contemporary applications of Artificial Intelligence (AI) and Machine Learning (ML). Large datasets are represented and processed efficiently by most AI algorithms using mathematical structures including vectors, matrices and tensors. In AI systems, it is common to have datasets organized in the form of a matrix with the rows referring to observations and columns referring to features. Pattern recognition and high dimensional data computations are efficiently calculated and transformed by means of linear algebra operations like matrix multiplication, eigenvalue decomposition and vectors transformation. Linear algebra is significant in neural networks, which is one of the fundamental tools of AI. The input data are in form of vectors and the weights among the neurons are in the form of matrices. Training and optimization algorithms of the gradient descent are performed by performing matrix multiplications and performing operations on vectors. Equally, the methods such as Principal Component Analysis (PCA) employ eigenvectors and eigenvalues to minimize the data dimensionality and maintain significant data. Linear algebra is also critical in computer vision, natural language processing, and recommendation systems. To take a simple example, in image representation, pixel values are expressed in matrices, whereas in natural language processing, word representations are expressed as vectors to represent semantic relationships. As such, the mathematical foundation offered by linear algebra makes it possible to compute, scale, and be accurate in modern AI applications efficiently.

Keywords: Linear Algebra, Artificial Intelligence, Prediction, Applications, Python Programming

1. Introduction:

Artificial Intelligence (AI) is one of the major technological advances of the recent past to dominate diverse sectors of healthcare, finance, education, agriculture, transportation. Most of the AI methods are based on mathematics to work with and analyze big data effectively. One of such mathematical tools is linear algebra, which is very essential in designing and executing the modern AI algorithms. It offers an organized method of data representation and computing that is needed by the machine learning and deep learning models. Data in AI is often organized in vectors and matrices, and they enable large data sets to be manipulated and stored effectively. Algorithms: Linear algebra The operations of linear algebra like matrix multiplication, transformation of vectors and eigenvalue decomposition are common in many AI algorithms. The operations assist in the optimization of models, the derivation of meaningful features and accuracy of prediction. An example to illustrate is that neural networks contain matrices to describe weights and biases, and training algorithms are sensitive to repeated linear algebra manipulations. moreover, even more modern AI algorithms, such as dimensionality reduction, recommendation systems, computer vision, and natural language processing, rely on the ideas of linear algebra. Reducing the complexity of the data and enhancing the computational efficiency is carried out by methods such as Principal Component Analysis (PCA) and Singular Value Decomposition (SVD). Thus, the knowledge of linear algebra is crucial in the creation of effective AI models and further development of intelligent systems of the present day.

2. Methodology

This research approach will aim at examining the use of linear algebra in contemporary Artificial Intelligence (AI) applications by conceptual analysis and computational demonstration. The paper begins with a review of the basic concepts in linear algebra including vectors, matrices, matrix multiplication, eigenvalues, and eigenvectors, which are the mathematical foundations of most AI algorithms. These are concepts that are looked at in order to learn their application in machine learning and deep learning models.

The paper then examines how the linear algebra is applied in popular AIs. The AI models analyze data through the use of vectors and matrices structures where each dataset is presented in the form of a matrix, with the rows being the observations and the columns the features. This data is then processed using linear transformations and matrix operations.

As an illustration of the usefulness of linear algebra, a basic example of

machine learning is applied using a regression model. Under this method, input data is expressed as matrices and vectors and model parameters are estimated by the use of matrix operation. Parameters are updated by gradient descent and this is the reason why the use of vectors and matrices calculations is emphasized during the training.

Besides, dimensionality reduction methods are also discussed like Principal Component Analysis (PCA) which is said to depict how eigenvalues and eigenvectors can be used to simplify data. The given methodological framework assists in proving how linear algebra provides the computational basis of the current AI applications.

3. Numerical Example:

To demonstrate the role of linear algebra in Artificial Intelligence, consider a simple linear regression model used for prediction. Suppose we have a dataset representing the relationship between study hours and exam scores.

Let the input data be represented in matrix form:

$$A = \begin{bmatrix} 1 & 2 \\ 1 & 4 \\ 1 & 6 \end{bmatrix} \text{ and } y = \begin{bmatrix} 50 \\ 65 \\ 85 \end{bmatrix}$$

Here, the first column of X represents the bias term and the second column represents the number of study hours. The vector YYY represents the exam scores.

The regression coefficients are calculated using the normal equation:

$$B = (X^T X)^{-1} X^T Y$$

First compute:

$$X^T X = \begin{bmatrix} 3 & 12 \\ 12 & 56 \end{bmatrix}$$

Then,

$$(X^T X)^{-1} = \begin{bmatrix} 2.33 & -0.5 \\ 0.5 & 0.125 \end{bmatrix}$$

Then,

$$B = \begin{bmatrix} 3.5 \\ 7.5 \end{bmatrix}$$

Thus, the regression model becomes:

$$\text{Score} = 35 + 7.5 \times (\text{Study Hours})$$

4. Python Program:

```
import numpy as np
X = np.array([[1,2],
              [1,4],
```

```
[1,6]])
Y = np.array([[50],
              [65],
              [80]])
XT = X.T
XTX = np.dot(XT, X)
XTX_inv = np.linalg.inv(XTX)
XTY = np.dot(XT, Y)
beta = np.dot(XTX_inv, XTY)
print("Regression Coefficients:")
print("Intercept ( $\beta_0$ ) =", beta[0][0])
print("Slope ( $\beta_1$ ) =", beta[1][0])
study_hours = float(input("Enter study hours: "))
predicted_score = beta[0][0] + beta[1][0]*study_hours
print("Predicted Score =", predicted_score)
```

5. Result and Discussion

The mathematical example illustrates why a basic predictive model in Artificial Intelligence can be constructed and computed using linear algebra. The regression coefficients were obtained in an efficient manner by using the matrix representation of input data and the normal equation. The findings show that the increment in the exam marks is about 7.5 marks per hour of study time. Computationally, the intercept value of 35 indicates the initial or baseline score of study hours which could have been previous knowledge or base level performance. Mathematically, this example shows the usefulness of the matrix operations in solving a regression problem; matrix multiplication, transpose, and matrix inverse. Linear algebra offers a more efficient and systematic method of solving multiple equations when they are too many and unwieldy to solve by hand, and in contemporary AI systems, analogous linear algebra methods are used in more complicated algorithms like neural networks, recommendation systems, and image processing models. Big data is defined as a type of data represented in the form of the matrices and worked out with the high-dimensional vector operations. Hence, the example shows that linear algebra is the mathematical premise to develop scalable and efficient AI models that are applicable in the real world.

6. Conclusion

The field of Linear algebra is important to the creation and deployment of

contemporary Artificial Intelligence (AI) and Machine Learning (ML) applications. The majority of AI models are based on math related structures, including vectors, matrices, and tensors, to store and operate huge amounts of data effectively. Mathematical computations like matrix multiplication, vector rotation, eigenvalue analysis, and matrix inversion are the fundamental computations of most AI algorithms. The mathematical case study introduced in this paper shows that the linear algebra methods may be used to construct a simple regression model to predict. The model parameters can be calculated by the use of matrices and their operations, thus, making the computation of the model parameters efficient. This method is even more essential when managing big data and complicated models that are employed in practice in AI.

Thus, researchers, data scientists, and developers of AI need to have a good grasp of linear algebra. It does not only enhance the theoretical knowledge of AI models but also increases their scale and computational efficiency. With the further development of AI, the significance of linear algebra as a mathematical instrument will be relevant in the development of intelligent technologies.

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Ethical Hacking and Cyber Security Against Cyber Attacks

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Abstract

This Paper Explore the critical role of cyber security and Ethical hacking in protecting Digital Infrastructure. It investigates the types of hackers, Application of ethical hacking and emerging challenges in the cyber security domain. The research underscores the importance of proactive security measures in a rapidly evolving digital landscape.

Keywords: Cyber Security, Cyber Crimes, Ethical Hacking.

1. Introduction

The protection of information and infrastructure is that security in which the chance of successful yet undetected theft, modification and disturbance of information and services are kept to low endurable. Network Security: Protecting a network and data, computer program, other computer system assets from unwanted intruders, and unauthorized user.

2. Hacking and challenges:

A hacker is an individual who uses his technical skills with the help of computer and network to process the task. Hacker is a person who uses his efforts to gain unauthorized access to systems and networks in order to commit cyber-crime. He may steal all the important information like all bank accounts, all personal data and use it to exploit the victim and ask for ransom wares to give data back.

3. Types of hackers in the present world:

a) White Hat Hackers:

Hacking for finding out the loop holes in the security system. White hat hackers, sometimes referred to as ethical hackers, assist system owners in detecting and fixing security systems vulnerabilities. They are referred to as ethical hackers

because they do not violate laws, even though they use many of the same tools used by Black Hat hackers.

Mission: To protect organization

Personality Trait: Ethical

Purpose: White Hat Hackers are hired to find security holes or vulnerabilities in existing cyber systems, so they can be patched and security test.

b) Black Hat Hackers:

Hacking for illegal or malicious purposes. Black Hat hackers, sometimes called crackers, are typically motivated by the personal gain they receive from illegally breaching computer systems, though they might also be social mischief-makers that are in it for the thrill of the attack, for revenge or to seek notoriety.

Mission: To profit from data breaches

Personality Trait: Malicious

Purpose: Black Hat Hackers conduct unauthorized and illegal cyber-attacks for stealing personal or organization information or data to sell for profit or personal use.

c) Grey Hat Hackers:

Hacking sometimes legally and sometimes not but has no malicious intentions. Grey Hats can have ideological motivations that translate to hacking attacks against an adversarial political position, a company policy that they do not agree with or even a nation-state. They are often referred to as activists. Grey Hat hackers can be White Hats by day and work for organizations and system owners to detect flaws in systems and mitigate them, but they sometimes engage in ideological hacking activities to correct a perceived wrong.

Mission: To protect organization

Personality Trait: Ambitious

Purpose: Gary Hat Hackers search for and exploit security vulnerabilities without profit and without authorization.

d) Ethical hacking:

Ethical hacking is the authorized practice of testing computer systems, networks, and applications to identify security weaknesses. It helps organizations fix vulnerabilities before malicious hackers can exploit them.

- Performed with legal permission from the system owner.
- Identifies vulnerabilities, risks, and security flaws.
- Helps strengthen system and network security.
- Uses the same techniques as attackers, but ethically.
- Plays a vital role in cybersecurity and risk management.

Ethical Hacking has been used for software and network security. Ethical hacking is performed with the target's permission. Such type of hacking is intended to discover vulnerabilities from various types of future malicious attacks for betterment of secured system. It is the part of security enhancement program that cover risks and allowing cyber security improvement penetrations legally. Ethical hacking can also use for testing the security by vendors. Ethical hacking is performed in controlled environment by performing ethical attacks. This helps better to understand the working of malicious codes and their range dangerous area. Generally, the ethical hacking term is used for security professionals for using their skills for defensive purpose to identify future security attacks in the system with good intension.

The term 'hacker' originated at MIT in the 1960's to describe someone who had the ability to understand and manipulate technology. Although this is still true of hackers, their skills have evolved outside of just technical capabilities to include the ability to manipulate people. Additionally, hackers are now categorized into three distinct categories that identify their motives.

4. Process of ethical hacking:

The preplanning is arranged in various steps for performing ethical attack to the system security testing legally. All technical, management and strategic issues must be considered. Proper planning is very crucial for security testing from simple password security test to all high-level network penetration tests. Back up of data and information should be kept before committing ethical hacking. So, a well-defined scope involves the following information

1. Specific systems to be tested.
2. Risks that are involved.
3. A proper test schedule is prepared over time.
4. Use knowledge or experiences to explore security threats.



5. What is cyber?

The term cyber and cyberspace are modernized due to spread of computer and internet connectivity. Anything related to the internet also falls under the cyber category. Some popular words that use the cyber prefix include the following: Cyber-crime, Cyberspace, Cyber forensics, Cyber bully, Cyber buck, Cyber security and Cyber punk.

6. Cyber-attacks and cyber security:

Cyber-attacks cause unauthorized access or manipulation, destruction, interruption in software in terms of malware intentionally to cause loss through electronic information or other physical infrastructure. There is a way to protect from these attacks is social awareness about cyber-crimes. It can be described as a process of applying information security measures or techniques to protect the confidentiality, integrity, and availability (CIA) of information. Hackers can compromise the confidentiality, integrity, and availability (CIA) of information by using social engineering attacks to naïve users.

7. Trends changing cyber security:

The various impact of cyber security attacks on the communication infrastructures:

7.1 Web servers:

Web applications are used to extract data or information by using malicious code on servers. Such cyber criminals distribute their malicious code via their compromised web servers. Now we have to focus on the protection of web servers and web applications because web server contains the valuable information and data. We should also use the safe web browser for financial transactions.

7.2 Cloud computing and its services:

The world is slowly moving towards the cloud. This latest trend presents a big challenge for cyber security against cyber-attacks, as traffic can go around traditional points of inspection. Additionally, as the number of applications available in the cloud grows, policy controls for web applications and cloud services will also need to progress in order to prevent the loss of important information.

7.3 Common cyber-attack:

Un-targeted Attacks

In un-targeted attacks, attackers randomly target as many devices, services or users as possible. They do not care about who the victim is as there will be a

number of machines or services with weakness. To do this security issue, they use techniques that take advantage of the openness of the Internet, which include: Phishing - sending emails to large numbers of people asking for sensitive Information (such as bank details) or encouraging them to visit a fake website. Water holding-setting up a fake website or compromising a legitimate one in order to exploit visiting users.

Aspect	Ethical Hacking	Cyber Security
Concept	Ethical hacking aims to discover system vulnerabilities through penetration testing and identify weaknesses.	Cyber Security employs technology and strategies to safeguard systems from cyber threats, breaches, and attacks.
Role	This is considered an offensive role.	This role is typically defensive in nature.
Objective	The primary goal is to locate and address vulnerabilities using various hacking techniques.	Its main objective is to defend data and systems from malicious actions by identifying and addressing security flaws.
Responsibility	Responsibilities include documenting vulnerabilities and detailing the hacking process.	Responsibilities involve creating and managing access controls on systems.
Tools & Techniques	Techniques include phishing, SQL injection, cryptography, social engineering, sniffing, session hijacking, and enumeration.	Tools used include encryption software, firewalls, web vulnerability scanners, penetration testing tools, network security monitoring, and packet sniffers.
Salary	€64,000 to €156,000.	€50,000 to €115,000.

8. Conclusion

Ethical hacking is a proactive, indispensable component of modern cybersecurity, essential for identifying vulnerabilities before malicious actors exploit them. By simulating real-world attacks, it strengthens digital resilience and enables proactive defence. Effective cybersecurity requires combining ethical hacking with AI-driven monitoring, ongoing training, and robust legal frameworks.

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A Review on RSA Cryptography: Cryptographic Algorithm Using Eleven Prime Numbers to Secure Communication

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Abstract

Cryptography is the science of securing data. It helps protect information as it travels over insecure networks like the internet. In cryptography, a set of algorithms, keys, and procedures work together to ensure secure communication through encryption and decryption. The main parts of a cryptographic system include plaintext, an encryption algorithm, a key, ciphertext, and a decryption algorithm. Plaintext is the original message that needs protection. An encryption algorithm is a mathematical process that transforms plaintext into ciphertext using a key. Ciphertext is the encrypted, unreadable form of the message. A decryption algorithm is the process that converts ciphertext back into plaintext using the correct key. There are two types of keys namely symmetric and asymmetric. The RSA algorithm uses an asymmetric key. RSA is based on fundamental concepts of number theory, particularly the properties of prime numbers and modular arithmetic, to encrypt and decrypt data. This paper presents a modified RSA cryptosystem algorithm called "Asymmetric Key based on cryptographic algorithm using eleven prime numbers as key to secure data in the communication."

Keywords: Modular Arithmetic, Euler's Totient Function, Modular Multiplicative Inverse, Exponentiation Modulo, Prime numbers, Plaintext, Ciphertext, Encryption, Decryption.

1. Introduction

Cryptography is the fundamental aspect of securing information. The term cryptography is derived from the Greek words cryptos and graphein, meaning secret and writing, respectively. Cryptography is a scientific field that studies mathematical techniques related to securing information including confidentiality, integrity, and authentication. According to Schneier, Cryptography is the science of maintaining data security. This includes maintaining confidentiality, ensuring data integrity, proving the sender's identity, and preventing the sender's deniability.[2]

Cryptography algorithms are two types and identified as symmetric/asymmetric cryptography. The essential difference between these two types of encryption/ decryption depends on the fact that symmetric cryptography uses a single key that needs to receive the message that sent by the first side. While asymmetrical cryptographs contain a public key to encrypt data only. The private/public key is offered to everybody who desires to use this mend and send the data but in other hands the private key is set hidden at secured place, One of drawback is asymmetric encryption takes much more time than symmetric encryption.[7]-[8]

Encryption algorithm helps to encrypt plain text by using encryption key sometimes referred as public key or private key. Again at the receiver end, the cipher text is transformed into plain text by using private key or public key and the entire process is known as decryption. The process model of asymmetric key cryptography as given below.

RSA [3] is considered as the first real life and practical asymmetric key cryptosystem. It becomes de facto standard for public-key cryptography. Its security lies with integer factorization problem. RSA decryption using Chinese Remainder theorem Verma et al. [9] Proposed a model to improve decryption time of RSA using CRT. They also proposed to generated large modulus and cryptographic keys with small order of matrix.



2. Literature review

The concept of the RSA public-key cryptosystem originated from the work of Diffie and Hellman, who introduced the idea of exponential key exchange. The Diffie–Hellman scheme later became the second most widely used public-key algorithm after RSA. However, the earliest known description of a similar cryptographic system dates back to 1973 and was proposed by Clifford Cocks, a mathematician working at GCHQ, a British intelligence organization. Due to the high computational cost of implementation at that time and its top-secret classification, the system was neither deployed nor disclosed publicly until 1998.

In the autumn of 1976, Ronald Rivest, Adi Shamir, and Leonard Adleman, then young researchers at the Massachusetts Institute of Technology, began developing a new cryptographic approach. Rivest and Shamir, both computer scientists, focused on designing cryptographic concepts, while Adleman, a number theorist, attempted to break those designs to test their strength. After many attempts, Rivest eventually created an algorithm that Adleman was unable to compromise. This breakthrough led to the development of the RSA algorithm, named after the initials of its creators—Rivest, Shamir, and Adleman., The RSA algorithm has not been successfully broken (Ohya & Volovich, 2011).

3. Mathematical Background:

Modular Arithmetic: Modular arithmetic is a system of arithmetic in which numbers are considered based on their remainders after division by a fixed positive integer called the modulus.

Euler’s Totient Function: Euler’s Totient Function, denoted by $\phi(n)$, is defined as the number of positive integers less than or equal to n that are co-prime to n (i.e., their greatest common divisor with n is 1).

Modular Multiplicative Inverse: A number x is called the modular multiplicative inverse of an integer a modulo n if the product of a and x is congruent to 1 modulo n . $a \cdot x \equiv 1 \pmod{n}$.

Exponentiation Modulo n : Exponentiation modulo n refers to the operation of finding the remainder when a number raised to a power is divided by a positive integer n .

RSA Key Generation Process

RSA is an asymmetric cryptographic technique that uses public key and private key. The public key is shared openly and is used to encrypt data, while the

private key is kept secret and is used for decryption. A message encrypted with the public key can only be decrypted using the corresponding private key.

The key generation steps of the RSA algorithm are explained below:

1. Select two different prime numbers, denoted as p and q .
2. For better security, the values of p and q should be chosen randomly.
3. Calculate

$$n = p \times q$$

The size of n (in bits) determines the key length.

5. Compute Euler's Totient Function:

$$\phi(n) = (p - 1)(q - 1)$$

6. Choose an integer e such that:

$$1 < e < \phi(n) \quad \text{and} \quad \gcd(e, \phi(n)) \equiv 1$$

7. The value e is published as the public key exponent.

8. Calculate the private key exponent d such that:

$$d \equiv e^{-1} \pmod{\phi(n)}$$

9. The value d is kept secret and used as the private key.

Encryption:

The ciphertext C is generated using the public key as follows:

$$C \equiv M^e \pmod{n}$$

Decryption:

The original message can be recovered using the private key:

$$M \equiv C^d \pmod{n}$$

4. Worked Example

Step 1: Select the Eleven Prime numbers

$$a = 2, b = 3, c = 5, k = 7, d = 11, e = 13, f = 17, g = 19, h = 23, i = 29, j = 31$$

Step 2: Calculate of n

$$n = a * b * c * d * e * f * g * h * i * j$$

$$n = 2 * 3 * 5 * 7 * 11 * 13 * 17 * 19 * 23 * 29 * 31$$

$$n = 200,560,490,130$$

Step 3: Calculate of $\phi(n)$:

$$\phi(n) = (a-1) (b-1) (c-1) (d-1) (e-1) (f-1) (g-1) (h-1) (i-1) (j-1)$$

$$\phi(n) = (2-1)(3-1)(5-1)(7-1)(11-1)(13-1)(17-1)(19-1)(23-1)(29-1)(31-1)$$

$$\phi(n) = 1 * 2 * 4 * 6 * 10 * 12 * 16 * 18 * 22 * 28 * 30$$

$$\phi(n) = 30,656,102,400$$

Step 4: Calculation of 'e':

Select any number $1 < e < \phi(n)$, Let $e = 13$

Step 5: Calculation of 'd': $d * e \pmod{\phi(n)} = 1$

$$d * 13 = 1 \pmod{30656102400}$$

$$d = 2,358,161,723$$

$$\text{Public Key} = [e, n] = [13, 200560490130]$$

$$\text{Private Key} = [d, n] = [2358161723, 200560490130]$$

Encryption Using Public Key:

Given message m = 2

$$C \equiv M^e \pmod{n} \qquad C \equiv 2^{13} \pmod{200,560,490,130}$$

$$C \equiv 2^{13} \pmod{200,560,490,130} \qquad C \equiv 8192$$

Decryption Using Private Key:

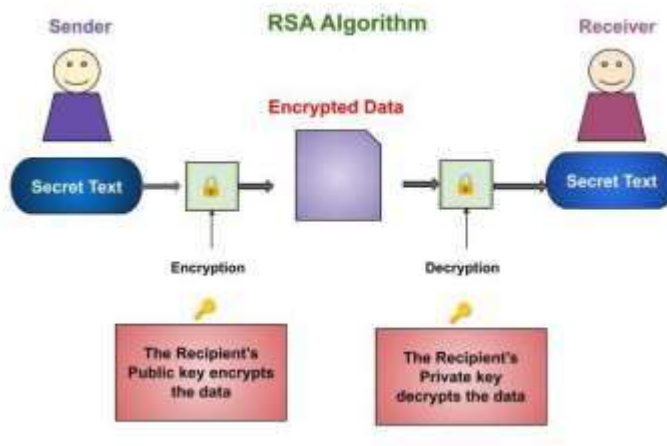
$$M \equiv C^d \pmod{n}$$

$$M \equiv 8192^{28,297,940,677} \pmod{200,560,490,130}$$

$$M \equiv 2$$

Original Message = 2

a	b	c	k	d	e	f	g	h	i	j	n	$\phi(n)$	e	d	m	C (Encrypted)	M (Decrypted)
2	3	5	7	1 1	1 3	1 7	1 9	2 3	2 9	3 1	20 0,5 60, 49 0,1 30	30,65 6,102, 400	13	2,358, 161,72 3	2	8192	1



5. Conclusion:

In this paper, cryptographic algorithm uses asymmetric key to encrypt the ciphertext. Transmission of data from one user to another done by symmetric key cryptography is very good to provide confidentiality but disadvantage is key distribution. The security for the cipher determined by the prime numbers chosen. For data security different types of cryptographic algorithms are available. Cryptographic algorithms based on number theory such as RSA, Elgamal, Diffie's -Hellman key exchange are widely used. This paper presented a cryptographic algorithm which is used to secure the data in the communication using eleven prime numbers as key.

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Beyond the Blackboard: Overcoming Math Anxiety in Indian Classrooms by Closing the Distance Between Rote-Memorization and Practical Applications

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Abstract

Despite being referred to as the "universal language," mathematics is more of a source of "mathematics anxiety" than a practical tool for millions of Indian students. This fear stems from a flawed system that puts exam scores, high-pressure private coaching, and rote memorization ahead of real comprehension rather than personal failure. However, studies and student feedback show that this anxiety vanishes when math is applied to real-world situations, such as budgeting or cricket scores. We can bridge the gap between abstract blackboard lessons and fascinating applications by implementing the useful, student-led solutions suggested by the National Education Policy (NEP) 2020. This will turn math from a subject of fear into one of joy.

Keywords: Anxiety, Ethnomathematics, Brain-freeze, NEP, NCF

1. Introduction: The Fear of Numbers in India

Math should be about problem-solving, yet it has become a cycle of memorizing shortcuts. In India, 2022 ASER¹ data show nearly half of Grade 8 students struggle with basic division, a crisis rooted in flawed teaching. Classrooms prioritize speed and rote copying over logic, causing students to panic when memory fails. This focus on "rule-following" destroys self-confidence.

The solution is replacing correctness with curiosity. By linking math to daily life and encouraging experimentation, the fear fades. When numbers feel alive, children shift from memorization to genuine insight.

2. The Roots of the Problem: How Did We Get Here?

India's reliance on rote learning is a legacy of its colonial past. Historically, Gurukuls emphasized practical mathematics—used for astronomy, architecture, and trade—through hands-on experience. However, the British educational reforms of 1835 shifted the focus toward training clerks. This system prioritized obedience and the exact repetition of facts over creativity.

Conceptual Learning vs. Rote Learning

Today, there is a clear divide between two types of learning: rote learning and conceptual learning.

- **Rote Learning:** This rote learning situation happens when a teacher says $2 ₹ + 2 ₹ = 4 ₹$ without giving any conceptual clarity of how to compute it or they just warn students to follow their teaching methods.
- **Conceptual Learning:** This is when a student understands the core idea. They know that if they have two apples and receive two more, they now have four apples. They can apply this logic to any object or situation.

3. The Heavy Burden of the Coaching Culture

Exhausted kids shuffle between school and tutoring, their days stretched thin by extra lessons meant to edge out rivals in college races. Success, many mothers believe, hides behind classroom doors lit by late-night study lamps. Four additional hours of drills pile onto packed schedules, sapping energy till minds feel hollow. Instead of exploring ideas, students memorize quick fixes that vanish under new kinds of questions. When unknown challenges appear, anxiety spikes - flexible thinking was never part of the routine.

4. How Math Anxiety Paralyzes the Brain

To solve the problem of math anxiety, we must understand what happens inside a student's brain when they feel scared of numbers. It is not just "butterflies in the stomach"; it is a real cognitive block.

The "Brain Freeze"

That moment when numbers vanish mid-test? Specialists name it Working Memory Interference Theory². Picture your mind's scratchpad - tiny, fleeting, juggling figures and logic. Stress floods in. Suddenly, worries crash through: "This is going wrong," or "They'll think I failed."

The Confidence Gap and Social Pressure

Another major factor is how students view themselves. If a student struggles with a rote-learning method, they quickly label themselves as a "non-math person." This low self-confidence makes them want to avoid math entirely. They stop

asking questions in class because they don't want to look slow or foolish in front of their friends.

5. Voices from the Indian Classroom: Primary Survey Findings

To truly understand how this anxiety operates, we must listen to the students themselves. A primary survey was conducted among Indian secondary students to gather their honest feelings about how mathematics is taught. The responses collected were incredibly revealing, pointing directly to the flaws of rote learning, the pressure of evaluations, and the vital role of the teacher's attitude. ⁵

6. The Impact of Teacher Attitude: Strictness vs. Empathy⁴

Out in classrooms where control runs tight, minds begin to shrink. Fear shows up when questions feel risky - Apeksha Abhijeet Chandanshive put it plainly: speaking up might mean being seen as slow. Silence grows because shame waits just behind confusion. Curiosity fades under pressure to perform without pause. Doubts pile up unseen, never cleared. When answers aren't safe to seek, learning loses its breath.

7. How to Solve the Problem: Practical Interventions

The good news is that math anxiety can be cured. It requires a shift from boring, memory-based teaching to exciting, practical, and friendly teaching. Based on the explicit advice given by the students in the survey and supported by educational research, here are the most effective ways to fix the system.

8. Cultivate Pedagogical Empathy and Destigmatize Mistakes

The most immediate solution lies in changing the classroom atmosphere. Teachers must create an environment where making a mistake is seen as a normal part of learning, not a reason for punishment.

- **Start from the Basics:** As advised by respondent Madiha Shaikh, teachers in high school should not blame students if they missed foundational concepts in 8th or 9th grade. Instead, teachers should start from "0" (the basics) and patiently help them build up to advanced topics, treating every student as capable of becoming a "Hero" in mathematics.
- **Stop the Insults:** As Satvik Singh strongly urged, teachers must stop insulting children after exam results come out. Labelling children as "bad students" kills their interest. Instead, teachers should analyse the test results to help students exactly where they are lacking.
- **Reduce Timed Pressure:** Respondent Prashant Babar correctly suggested using fewer timed tests. Since we know that a ticking clock causes a "brain freeze" by overloading working memory, removing unnecessary time limits allows students to actually think through the problem.

Connect Math to Daily Life and Explain the "Why"

Students are desperate to know why they are learning these concepts. If a teacher just writes a formula on the board, it feels like an alien language.

Everyday Examples: Students like Piyush S Nagarkar and Pratiksha Hari Shinde advised teachers to use everyday examples like shopping, cooking, or local puzzles. Showing how percentages work during a festival sale or how fractions work while cooking makes the math real and useful.

Explain the Origins of Formulas: Satvik Singh pointed out a major flaw: "Tell us about the real-life match... Why the formula of the circle is $2\pi r$. Why am I studying trigonometry. What are the applications... these things should be taught at the school level itself." Teachers must explain the origin of a formula before asking students to memorize it.

Student-Led Problem Framing: Chandni Kumari proposed a brilliant, interactive solution: students should be asked to frame their own real-life questions involving mathematics for other students to answer. This forces them to look at their own lives and apply mathematical logic to it.

Embracing "Ethnomathematics" (Culture and Math)

Out there among village courtyards, kids trace geometric shapes inspired by Rangoli designs, just like Chandni Kumari pointed out. Instead of textbooks alone, learning slips into daily life when Kolam drawings reveal symmetry bit by bit. Farming calendars based on moon cycles show how numbers guide real work. Through crafts and seasons, math becomes something lived, not memorized. Heritage holds quiet lessons - when recognized, anxiety around formulas fades. What once felt distant now feels familiar.

9. Conclusion

While math anxiety in India remains a significant roadblock, it is a solvable systemic issue. The current fear stems from an outdated reliance on rote memorization, high-stakes testing, and the exhausting pressure of coaching centres, which paralyze a student's natural reasoning. As students have noted, when memorized steps fail during "twisted" problems, panic replaces confidence. The path forward lies in bridging the gap between abstract formulas and reality. By leveraging students' intuitive skills in budgeting, puzzles, and sports, math becomes relevant and exciting. Success requires shifting the classroom culture toward patience and empathy, as mandated by the NEP 2020. By prioritizing deep thinking over rapid calculation, we can transform mathematics from a source of dread into a powerful tool for exploration.

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Big Data Analytics for Predictive Modelling Using Distributed Data Processing Frameworks

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Abstract

Nowadays in the digital world, an enormous amount of data is generated in one second in different forms such as text, images, audio and videos. The current data processing system is not capable of processing such huge and dynamic data. The digital transformation sees the organizations produce huge volumes of structured and unstructured data, which comes in the form of social media platforms, financial transactions, healthcare systems, IoT devices, and online services among others. The use of traditional database system to manage and analyse this fast-growing data has been a significant challenge owing to the constraints in the level of scalability, storage capacity, and processing speed. In order to eliminate these problems, Big Data technologies offer distributed storage and parallel processing.

In this paper, a scalable big data analysis system with big data technologies and machine learning algorithms is provided. Its distributed platform such as Apache Hadoop and Apache Spark is used to process big data fast and efficiently. An artificial intelligence model is created to identify trends in the data and make valuable predictive decisions. The outcome demonstrates that such a system is quicker, performs better with large data and provides more precise predictions.

Keywords: Data Science, Big Data Analytics, Machine Learning, Hadoop, Spark, Predictive Modelling.

1. Introduction

The volume of data created on a daily basis in the contemporary digital world is growing at an alarming rate. As the internet services, mobile devices, social media platforms, e-commerce systems, financial transactions, and the Internet of Things (IoT) devices continue to expand at an alarming pace, organizations are

generating and aggregating large volumes of data in various forms. This data may be in a structured, semi-structured or unstructured format in the form of text, images, videos, logs and sensor data. The ever-increasing size of such large-scale data has posed a lot of challenge in the context of storage, processing, analysis, and management of such data.

Data Science has become a significant discipline that integrates statistics, machine learning, data mining and data visualization in order to derive meaningful data and information about big data. Data science can help organizations learn the trends and make accurate predictions with the help of predictive analytics, classification algorithms, as well as pattern recognition techniques, enhancing decision-making processes. Scalable computing infrastructure is however needed to perform data science tasks on large datasets of extremely large scale.

To deal with these, there have been innovations of the Big Data technologies to allow the storage and processing of the data in a distributed manner and on a parallel basis. Apache Hadoop is one of the most popular frameworks of large-scale data processing that involves the Hadoop Distributed File System (HDFS) where large amounts of data are stored in a distributed environment in many nodes. Hadoop provides an effective batch processing through Map Reduce programming model. Apache Spark is another strong engine of Big Data processing that is even faster in-memory computing and accommodates other advanced analytics such as machine learning, streaming data processing, and graph analytics.

This study aims at creating a scalable system of Big Data analytics, based on distributed computing platform and machine learning methods. The suggested system is expected to be efficient in processing big data, creating predictive models, and measuring their effectiveness with the help of suitable evaluation metrics. Through distributed data processing technology and state-of-the-art analytics techniques, the study will enhance scalability, processing speed and accuracy of predictions as opposed to the traditional data processing systems. The results of this study can be used in developing effective data-intensive solutions to the current data-intensive applications.

2. Literature Review

Over the past years, the topic of applying the technologies and machine learning methods to process and analyze large-scale data has been studied by many researchers. The traditional information processing systems were predominantly created in structured data and limited datasets. Nonetheless, as the digital data

continues to grow at a high rate, scholars have paid attention to evolving distributed computing models to process and analyze high amounts of data with ease.

Predictive analytics systems that use machine learning to build systems by using Big Data platforms. Several machine learning methods including linear regression, decision trees, random forests, and support vectors machines have been used to process big data to determine patterns and provide predictions. Research has also indicated that machine learning integrated with the Big Data technologies helps organizations to identify valuable insights on complex datasets and enhance the decision-making process.

3. Methodology

The suggested system is dedicated to the creation of a scalable Big Data analytics system that incorporates the approach of distributed processing of data along with machine learning. The methodology has a series of steps such as data collection, data storage, preprocessing, model development and model performance.

Step 3.1: Data Collection

The task in this step entails the acquisition of a large amount of data through credible sources. The data set can contain the information of various areas like data of the stock market, medical records, or social media. The datasets are also normally made up of both structured and unstructured data. The information obtained will be taken as the input to further analysis and predictive modeling.

Step 3.2: Data Storage

The size of dataset is very enormous hence it cannot be stored efficiently using traditional database systems. Thus, the distributed storage system is employed. This information is stored through the Hadoop Distributed File System of the Apache Hadoop. HDFS enables data to be replicated on more than one node on a distributed system and thus is scalable, fault tolerant as well as efficient in managing data.

Step 3.3: Data Processing

The data is then stored and processed and analyzed with Apache Spark. Spark supports in-memory processing that is fast and thus enhances efficiency in computation. In this step, various data preparation activities are carried out and they include:

Data Cleaning: Eliminating missing data, multiple data, and non-congruent data.
Feature Engineering: The choice of significant variables and the development of new features to enhance model performance.

Data Transformation: Process of converting raw data into structured data which can be used by machine learning algorithms.

Step 3.4: Model Building

The processed dataset is then fed into machine learning algorithms to produce predictive models in this step. Patterns and relationships of the data are analyzed with different algorithms. The algorithms applied in this study are:

- Linear Regression
- Random Forest
- Gradient Boosting
- Logistic Regression

The processed dataset is used to train these models and their performance is compared to come up with the most accurate and efficient model.

Step 3.5: Evaluation Metrics

In order to measure the performance of the predictive models, a number of performance measures are applied. These measures assist in the measurement of the accuracy and reliability of the models.

- **Accuracy:** Determines the accuracy of the model predictions, on the whole.
- **Precision:** Refers to the percent of accurate positive predictions.
- **Recall:** Determines the capability of the model to detect the pertinent occurrences.
- **F1 Score:** Precision and recall.
- **Execution Time:** Evaluates the system efficiency in terms of computational efficiency.

Experimental Result

Model	Accuracy	Execution Time
Logistic Regression	87%	15 sec
Random Forest	92%	22 sec
Gradient Boosting	94%	30 sec

4. Conclusion

It has suggested a scaled-down model of Big Data analytics that processes and analyses large datasets through the use of distributed computing technologies and machine learning algorithms. The increased rate of digital data has burdened conventional data processing system because it cannot efficiently process mass data. In order to deal with this problem, Apache Hadoop and Apache Spark platforms were used to deliver distributed storage and high data processing rates. The paper presents the significance of integrating Big Data infrastructure and

highly sophisticated analytic techniques to aid decision-making that is informed by data. The framework suggested can be implemented in different areas including finance, healthcare, social media analytics, and smart cities applications. It is possible to consider adding real-time data processing, deep learning models, and cloud-based Big Data platforms to the system to make large-scale data analytics systems more efficient and capable in the future.

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Smart Energy Management Using IoT

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Abstract

The use of energy has grown tremendously over the past few years because of the high rates of industrialization and urbanization, as well as growing utilization of electronic devices. The conventional systems of energy management do not commonly have real-time monitoring and control that causes energy to be wasted and resources to be used inefficiently. The Internet of Things (IoT) gives rise to Smart Energy Management, which is an innovative solution to overcome these issues. The IoT technology enables devices, sensors, and systems to network with one another via the internet, which enables real-time monitoring and automated control of energy consumption. Smart meters and sensors are used in the IoT-based energy management systems to record data on appliances and electrical systems energy usage. This information is sent to cloud services where it is used to determine consumption trends and streamline energy consumption. The system is capable of automatically regulating the power consumption, minimizing wastage, and enhancing energy efficiency. This research paper will explain the idea of smart energy management through the IoT, motivation and background of smart energy management, definition, research methodology, discussion of the benefits and challenges of smart energy management, and conclusion made by the research.

Keywords: Smart Energy Management, Internet of Things (IoT), Energy Monitoring, Smart Grid, Energy Efficiency, Wireless Sensor Networks

1. Introduction

One of the most significant resources in contributing to the growth of economy and development of technology is energy. Nevertheless, the growing need of energy has posed a number of challenges among them being energy shortage, high cost of electricity and environmental pollution. The conventional energy

management system lacks effective processes that can be used to monitor and control real-time energy consumption. This leads to wastage of energy in residential premises, industries and business premises. With the introduction of the digital technology, the idea of the Internet of Things (IoT) was introduced, which involves the use of the internet to connect devices to communicate with each other and accomplish automatic tasks. The IoT technology has created new opportunities to create smart energy management systems that would be able to track and manage the energy consumption effectively.

The energy management systems are popular in smart homes, smart buildings, and smart cities based on IoT. The systems enable users to track the energy use, lower the electricity bills and encourage sustainable energy usage. The IoT is also integrated with renewable energy sources, which also leads to the efficient use of energy resources.

2. Motivation and Background:

The major reason that has led to the development of smart energy management systems is the growing global energy demands and the need to minimize wastage of energy. Rapid industrialization and expansion of population are forcing many countries to experience energy shortages. The conventional energy management systems give limited information regarding the energy consumption patterns. Sometimes users are not able to know which appliances use the most amount of electricity or how the energy consumption varies with time. This information deficiency renders it hard to manage energy consumption.

3. Literature Survey

The literature survey is a significant aspect of the research that examines past studies on the topic of the research. The use of an Internet of Things (IoT) technology in the management of energy systems to enhance efficiency and minimize the use of energy has been researched by many researchers.

The inclusion of renewable energy sources into IoT-based energy management systems has been investigated in other works. As an illustration, systems of solar power can be linked to IoT in monitoring energy production and use. This assists in enhancing the efficiency of the use of renewable energy.

The significance of data analytics and cloud computing in the energy management of IoT-based applications has also been discussed by researchers. The IoT devices create significant volumes of data that can be analyzed with advanced algorithms to determine the patterns of energy consumption and minimize energy usage.

4. Proposed Methodology

A Smart Energy Management System based on the IoT requires a number of steps to propose the implementation methodology.

Step 1: Data Collection

IoT devices, which include smart meters, sensors, microcontrollers, and others, are used to gather energy consumption information. These gadgets detect real time consumption of power.

Step 2: Device Connectivity

The sensors and smart meters will be linked by means of communication technologies, e.g. Wi-Fi, Bluetooth, Zigbee, or any other wireless networks. These networks of communication enable devices to send data to a central system.

Step 3: Data Transmission

The gathered data are sent to the cloud servers or databases that contain the data where they are processed and analyzed.

Step 4: Processing and Analysis of Data.

Energy consumption patterns are analyzed with the help of data analytics tools. The system detects the inefficient utilization of energy and indicates how it can be improved.

Step 5: Automated Control

According to the results of the analysis, electrical devices can be controlled by the system automatically. In this regard, one can switch off lights when a room is not used, or one can use the appliances in the most appropriate energy times.

Step 6: User Monitoring

The mobile applications or web dashboards allow users to track the energy usage. This enables them to monitor the consumption of electricity and make decision towards better management of energy.

5. IoT-Based Energy Management System System Architecture.

The IoT-based smart energy management system has a system architecture that is composed of a number of layers which collaborate in order to monitor and manage the use of energy.

5.1 Sensing Layer:

Sensors and smart meters are part of this layer and they record data concerning energy consumption. These sensors detect factors like voltage, current, power consumption, temperature and environmental factors.

5.2 Network Layer:

Network layer also deals with communication between IoT devices and the central system. Wi-Fi, Zigbee, Bluetooth, cellular networks are some of the technologies that have been commonly utilized to transmit data.

5.3 Data Processing Layer:

This layer stores the data collected and processed using the cloud computing platforms. The use of advanced data analytics is aimed at the analysis of energy consumption patterns and identification of inefficiencies.

5.4 Application Layer:

The user interfaces are offered through the application layer which includes mobile apps or web dashboards. These applications enable users to track energy consumption, device control, and have alerts on energy consumption.

5.6 Control Layer:

The control layer is an automatic controller of electrical objects in regard to the analysis of data. It is able to switch gadgets on or off, regulate power consumption, and streamline power consumption.

5.7 Implementation Strategies:

A smart energy management system based on IoT application has to be carefully planned and properly selected technology is needed. There are a number of strategies that can be embraced to guarantee successful implementation.

5.8 Deployment of Smart Meters:

Given that real-time monitoring of electricity usage is required, smart meters must be installed in homes, industries, and commercial buildings.

5.9 Integration of IoT Sensors:

The data on environmental conditions, occupancy, and use of the devices should be collected by sensors. The information assists in automating the energy management processes.

5.10 Use of Cloud Platforms: The IoT devices generate huge amounts of data that ought to be stored and processed via cloud computing platforms. Cloud computing offers extensibility and access.

5.11 Data Optimization and Analytics:

Patterns of energy consumption should be analyzed using sophisticated data analytics software. These instruments can assist in the determination of places where energy could be conserved.

5.12 Security Implementation:

The IoT systems should be secured against cyber threats by using security measures like encryption, authentication or secure communication protocols.

5.13 User Awareness and Training:

The users must be informed of the advantages of the smart energy management systems and be trained on the effective use of monitoring applications.

6. Conclusions

Smart Energy Management using IoT is an innovative approach to improving energy efficiency and reducing energy wastage. By using interconnected devices, sensors, and communication networks, IoT technology enables real-time monitoring and automated control of energy consumption.

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Applications of Data Structure in Artificial Intelligence and Machine Learning Training Models

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Abstract

The fast development of Artificial Intelligence (AI) and Machine Learning (ML) has made the efficient data handling, storage, and processing mechanisms highly demanded. The basic building blocks of these computational systems are the data structures which have been shown to be vital in improving the performance of the algorithms, use of memory and scalability. This article discusses the most essential use of both classical and modern data structures in AI and ML, with a specific focus on the way it affects the enhancement of the computational efficiency of the system and real-time smart systems. Implementing machine learning algorithms is based on traditional data structures, which include arrays, linked lists, stacks, queues, trees and graphs. As an example, decision trees and random forests would heavily rely on tree-based structures, whereas social network analysis and graph neural networks heavily rely on the use of graph structures. Likewise, hash tables and heaps can be used to improve the faster search and priority-based learning activities, which are used to reduce the time of retrieving data and optimization of the model.

These smart structures are scaled to the data distributions and enhance performance in activities including indexing, searching and data compression. In addition, the paper identifies some of the challenges that include dealing with dynamic streams of data, trade-offs between time and space and scalability in distributed settings.

Keywords: Computational, Data Structure, Algorithms, Decision Trees, Artificial Intelligence, Machine Learning

1. Introduction

Artificial Intelligence (AI) and Machine Learning (ML) are the fields that have been experiencing unprecedented growth in the recent years due to the exponential growth in the data generation and the available computational power. AI systems have become part of complex real-world solutions, in healthcare diagnostics and financial forecasting, as well as natural language processing and computer vision. But, the performance and scalability of such systems lie in both the advanced algorithms and underlying data structure that is effective at organizing, storing, and processing data. The foundation of any computational system is its data structures where they facilitate well-structured data manipulation and retrieval. When dealing with big data volumes and high-dimensional data, especially in the framework of AI and ML, the selection of the data structure of a particular type is key. Data structures like arrays, linked lists, stacks, queues, tree and graph have been extensively exploited to implement core machine learning algorithms. As an example, decision trees and random forests are based primarily on tree hierarchies, whereas graphs are core to the description of social network and recommendation system relationships, as well as in graph neural networks. Equally, hash tables enable rapid access to data which is necessary in processes like feature mapping and caching compromised data in model training.

A combination of algorithm design and machine learning is bringing a paradigm shift in the way information is handled in modern AI systems. Another part of the paper also discusses the use of data structures in practice, such as healthcare analytics, financial modeling, natural language processing, and computer vision. This paper focuses on discussing the role and uses of data structures in AI and ML along with their effect on the efficiency of algorithms and performance of a system. It gives general information on both the classical and modern data structures, how they are used in different fields, and the future developments and research. This study will help advance smoother and smarter computational systems by filling the gap between the design of data structure and machine learning.

2. Methodology



3. Numerical Example

The following program illustrates the numerical example implemented in Python using NumPy and KDTree of SciPy. The findings establish that KD-tree greatly minimizes the number of computations with no changes in the classification accuracy scenario as compared to that of the brute-force method.

3.1: Python Program:

```
import numpy as np
import matplotlib.pyplot as plt
from scipy.spatial import KDTree
from collections import Counter
X = np.array([
    [2, 3], # A
    [5, 4], # B
    [9, 6], # C
    [4, 7], # D
    [8, 1], # E
    [7, 2] # F
])
y = np.array([0, 0, 1, 1, 0, 1])
# New point
P = np.array([6, 3])
k = 3
def euclidean_distance(a, b):
    return np.sqrt(np.sum((a - b) ** 2))
distances = []
for i in range(len(X)):
    d = euclidean_distance(P, X[i])
    distances.append((float(d), int(y[i])))
distances.sort(key=lambda x: x[0])
neighbors_brute = distances[:k]
labels_brute = [label for _, label in neighbors_brute]
prediction_brute = Counter(labels_brute).most_common(1)[0][0]
tree = KDTree(X)
dist, idx = tree.query(P, k=k)
neighbors_kdtree = [(float(dist[i]), int(y[idx[i]])) for i in range(k)]
labels_kdtree = [label for _, label in neighbors_kdtree]
prediction_kdtree = Counter(labels_kdtree).most_common(1)[0][0]
```

```

print("Brute Force KNN:")
print("Nearest Neighbors:", neighbors_brute)
print("Predicted Class:", prediction_brute)

print("\nKD-Tree KNN:")
print("Nearest Neighbors:", neighbors_kdtree)
print("Predicted Class:", prediction_kdtree)
plt.figure()
for i in range(len(X)):
    if y[i] == 0:
        plt.scatter(X[i][0], X[i][1], marker='o', label='Class 0' if i == 0
else "")
    else:
        plt.scatter(X[i][0], X[i][1], marker='s', label='Class 1' if i == 2 else
        "")
plt.scatter(P[0], P[1], marker='*', s=200, label='New Point')
for i in idx:
    plt.scatter(X[i][0], X[i][1], edgecolors='black', s=200)
for i in idx:
    plt.plot([P[0], X[i][0]], [P[1], X[i][1]], linestyle='--')
plt.title("KNN Visualization (Brute Force vs KD-Tree)")
plt.xlabel("X-axis")
plt.ylabel("Y-axis")
plt.legend()
plt.grid()
plt.show()

```

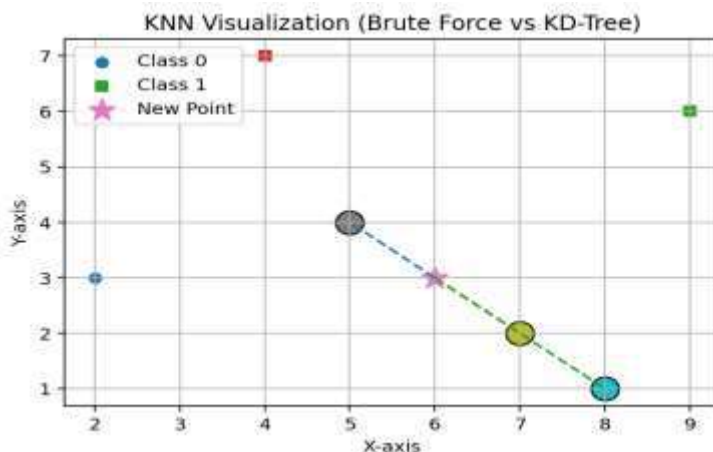
3.2 Output Obtained:

```

In [3]: %runfile C:/Users/DELL/untitled2.py --wdir
Brute Force KNN:
Nearest Neighbors: [(1.4142135623730951, 0), (1.4142135623730951, 1), (2.8284271247461903, 0)]
Predicted Class: 0

KD-Tree KNN:
Nearest Neighbors: [(1.4142135623730951, 0), (1.4142135623730951, 1), (2.8284271247461903, 0)]
Predicted Class: 0

```



4. Results and Discussion

The tests of the KNN algorithm were performed based on the brute-force algorithm and the KD-tree data structure on experimental data. The findings of both the procedures indicate that the closest neighbors found with respect to the query point $P(6,3)$ are the same, and hence the same predicted class label (Class = 0). This proves the fact that the performance of the classification of the model is not influenced by using high data structure like KD-tree. Nevertheless, one of the main differences is observed in efficiency in calculation. The brute-force method calculates the distance between the query point and each data point, therefore; the time complexity is $O(n)$. Conversely, KD-tree method minimizes the distance computations, by subdivision of data space, which has an average complexity of time of $O(\log n)$ Although this is a small dataset, the KD-tree makes fewer comparisons, which also shows that it is more suitable to large datasets.

The graphical representation also goes a step further in proving the accuracy of the results by providing a clear indication of the nearest neighbors and the spatial relationship of the query point with them. Most of the voting mechanism is correct query point classification, basing on the dominant attribute of the nearest and closest neighbors.

5. Conclusion

This paper brings out the importance of data structures in improving the effectiveness and performance of Artificial Intelligence (AI) and Machine Learning (ML) algorithms. With the application of the k-Nearest Neighbors (KNN) algorithm both in the brute-force mode and the KD-tree mode, it is observed that the two methods yield the same classification to the extent that the structure of data chosen significantly affects the efficiency of computation. Being an advanced data structure, the KD-tree minimizes the number of computing

distances and enhances search rates, particularly when the dataset size and dimensions grow. The findings prove that data structures are not auxiliary elements but the key factor in deciding the scalability and responsiveness of machine learning systems. The benefits of the efficient data organization are the acceleration of data processing, optimized memory consumption, and the possibility to work with a large amount of data that are crucial features in the contemporary AI-based tool of real-time prediction, big data analytics, and intelligent decision-making systems. Moreover, the paper underlines the necessity to combine proper data structures with machine learning algorithms so that the performance could be improved without losing any accuracy. The visualization methods also contribute to comprehending the behavior of the algorithm and prove the findings appropriately. Finally, the research confirms the strategic use of data structures, including KD-trees is essential in enhancing AI and ML models efficiencies. It is possible to investigate more complex and adaptive data structures including learned data structures and hybrid models to be used in the future to improve performance in intricate and high-dimensional problem domains.

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Recent Trends in Cloud Computing and Edge Computing

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Abstract

Two important paradigms that changed the modern computing infrastructure are cloud computing and edge computing. Cloud computing offers computing resources on-demand like storage, processing power, and applications via centralized data centers via the internet. Nonetheless, as the Internet of Things (IoT) devices and real-time applications develop rapidly, the traditional cloud systems have become problematic due to latency, network congestion and bandwidth constraints. Edge computing has become a complement to solution that works with the data source, so the data processing time is reduced, and the work is better compared to operating on a central server. This research paper discusses the phenomenon of cloud computing and edge computing, their definitions, architecture, research, and research methodology of these technologies. Their integration is also analyzed in the paper and how the edge-cloud model increases the efficiency of the system in the context of new uses like smart cities, healthcare, autonomous vehicles, and industrial automation.

Keywords: Cloud Computing, Edge Computing, Distributed Computing, Internet of Things (IoT), Data Processing, Low Latency, Network Architecture

1. Introduction

Over the past few years, there has been a huge surge in the need to have more computing power, data storage, and effective data processing as brought about by digital transformation. Cloud computing was a breakthrough technology which enables users to access computing resources remotely via the net. It offers scalable, flexible and affordable solutions to individuals and organizations.

Edge computing has been proposed to solve these issues. Edge computing computes and records information at the place where the information originated instead of transmitting it to remote cloud computing hubs. This will minimize the

latency and will allow real time decision making. Research indicates that edge computing spreads computing resources nearer to devices to minimize delays and provide applications that need instant responses.

Cloud and edge computing are not in competition with each other but complementary models, which when used together make a formidable distributed computing environment.

2. Definition of Cloud Computing and Edge Computing

2.1 Cloud Computing

Cloud computing is a technology through which it offers access to shared computing facilities like servers, storage, databases, networking and software on-demand basis and via the internet. These are services that are hosted on centralized data centers as operated by cloud service providers.

The main peculiarities of cloud computing are:

On-demand self-service

Resource pooling

Rapid scalability

Broad network access

Pay-as-you-use model

Web applications, data analytics, enterprise systems, and massive data storage are some of the common applications of cloud computing.

2.2 Edge Computing

Edge computing is a paradigm of distributed computing that runs processes nearer to the data source, e.g. sensors, IoT devices, or local servers. Edge computing processes data at the network edge instead of transmitting all data to the centralized data centers in clouds.

Applications of edge computing are:

Autonomous vehicles

Smart cities

Industrial automation

Healthcare surveillance systems.

AR applications.

Literature Review

The connection between edge computing and cloud computing is an issue that is investigated by numerous researchers.

In the recent research findings, it has been revealed that cloud computing offers a very strong centralized infrastructure that has the capacity to process and store

large amounts of data. Nonetheless, the growing list of devices being interconnected generates enormous amounts of data that can delay when sent to remote cloud servers.

The other research trend is on the combination of artificial intelligence and machine learning with edge computing. This allows smart data analysis at the edge devices without being strictly dependent on the cloud resources. Generally, the literature indicates that cloud and edge computing can be integrated to provide a scalable and efficient architecture that can support the current digital applications.

3. Research Methodology.

The research paper will use a qualitative research methodology, which will be grounded on secondary data analysis. The following steps make part of the methodology:

3.1 Literature Collection

The digital libraries and academic databases were used to retrieve research articles, journals, conference papers, and academic sources on cloud computing and edge computing.

3.2 Comparative Analysis

The literature gathered was studied in order to see the differences and similarities between cloud computing and edge computing.

3.3 Development of Conceptual Framework.

The conceptual model was created based on the analysed literature to define the structure and communication between cloud and edge systems.

3.4 Synthesis of Findings

The last phase was the synthesis of the research outcome and the presentation in a structured form in the form of definitions, architecture, advantages, and applications.

This approach contributes to the advanced perception of the technologies and the developments of their research.

3.5 Cloud Computing Architecture.

Cloud computing architecture typically is made up of two major components:

Front End

Back End

Front End

The user interface or the client side of the cloud system is known as the front end. It encompasses equipment like computers, mobile phones or web browsers that the users use to gain access to cloud services.

3.6 Back End

The cloud infrastructure where services are hosted makes up the back end. It includes:

Servers

Storage systems

Databases

Virtual machines

Cloud management software

The back end accepts user requests and provides services via the internet.

3.7 Cloud Service Models

Three types of services are usually supported by cloud computing architecture:

Infrastructure as a Service (IaaS) - Virtual machine and storage.

Platform as a Service (PaaS) - offers applications development platforms.

Software as a Service (SaaS) - It is the provision of software applications through the internet.

These models enable organizations to decide the extent of control and management that they need.

3.8 Edge Computing Architecture.

Edge computing system is built to be able to process data near data creating devices. An average edge computing architecture is composed of three principal layers:

3.9 Device Layer

IoT devices, sensors, smartphones, and other data-generating devices are contained in this layer. These are gadgets that gather information on the physical environment.

4. Comparison of Cloud Computing and Edge Computing

Feature	Cloud Computing	Edge Computing
Processing Location	Centralized data centers	Near data source
Latency	Higher latency	Low latency
Bandwidth Usage	High	Lower
Scalability	Very high	Limited compared to cloud
Best Applications	Data storage, analytics	Real-time systems

Both technologies work best when integrated into a hybrid architecture.

5. Applications of Cloud and Edge Computing

5.1. Smart Cities

Traffic and environment data is processed by edge devices and big datasets are stored and analyzed in cloud systems.

5.2. Healthcare

The wearable devices are used to monitor patients in real-time through edge computing and store their medical records on cloud systems.

5.3. Autonomous Vehicles

Edge computing is applied to real-time decision making in vehicles and cloud systems to train AI models on a large scale.

5.4. Industrial Automation

Edge computing is used in factories to monitor machines and make predictions on their maintenance.

6. Conclusion

Modern digital infrastructure needs cloud computing and edge computing. Cloud computing provides centralized and scalable computing and storage resources that can process and store huge data. Nevertheless, the increasing need in real-time applications and internet of things devices have highlighted the shortcomings like latency and bandwidth.

Edge computing is one solution to these problems by computing nearer to the source so as to minimize delays and enhance the response time. Fusion of edge and cloud computing leads to the formation of a hybrid architecture, which integrates the two models with their respective advantages.

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SLIM21 and KOHA Library Automation Software's: A Comparative Study

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Abstract

Library automation software is very important aspect for library. Selection of right software for library and Information centers is a challenge for librarians. SLIM 21 and KOHA software are used in many libraries. Researcher compared both software considering all the aspects advantages, disadvantages, service providers, training facility, etc. This research paper will help to the librarian to select library automation software.

Key Words: Software, SLIM 21, KOHA.

1. Introduction

Software package is the most crucial for the success of library automation as it has many implications for a library is operations services staff and users. The success of library automation depends largely on the selection of right software and its effective implementation. A wide variety of library software packages are available in the market. Selection of an appropriate package suited to a particular library and its intelligent implementation are challenging computer task in library automation process. Therefore, libraries should evaluate and compare all the available software packages carefully in order to select the best one that can match both the priority requirements and available financial resources.

2. Need of the Study

Today's Libraries are hybrid libraries. Resources are available in print format and digital format to provide quality services to the user's efficient administration of the library. Automation of the library is very essential. Library software the main part of the library automation, hence the selection of the library software is very important. SLIM21 software is available commercially. Some Open-Source Software (OSS) packages are available on Internet. KOHA is Open-Source Software for Library Information Management.

3. Objectives of the study

1. To Study the SLIM21 Library software.
2. To study the KOHA Library Software.
3. To study comparatively SLIM21 and KOHA Library Software's

4. Scope of the study

The topic of the research work reflects its scope is to determine and analysis true various dimensions of SLIM21 and KOHA users in Pune city. It may be desirable to explain have as to why only two software packages were selected for present study. Researcher is interested to study SLIM21 because many libraries in Pune city are using SLM21.KOHA is Open-Source Software (OSS) package, available freely but use of this software are less in Pune city.

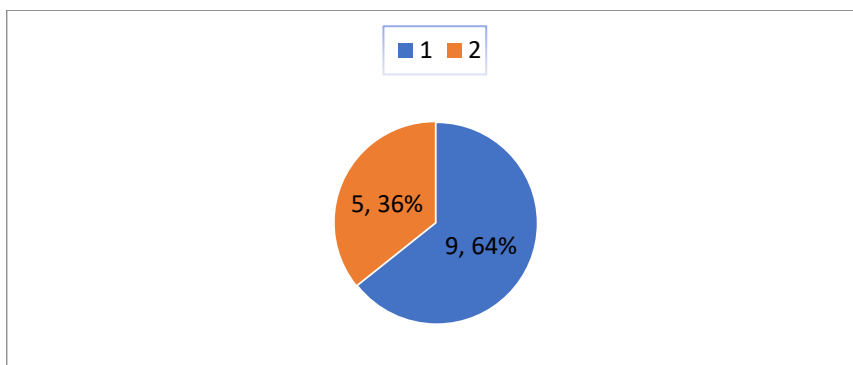
5. Methodology

Comparative research is a logical extension of descriptive studies. While descriptive studies focus on a single object / entity/ sample / system, comparative once cover description of more than one. Here more than one similar systems or samples are compared based on predetermined parameters that are relevant to the objective / hypothesis. Comparative studies lead to better understanding of the object of the study.

5.1 Colleges and Institutions are using SLIM21 and KOHA Library Automation Software's

Following chart shows the users of SLIM21 and KOHA open-source Library automation software. There are five Colleges are using KOHA Open-Source Software and nine colleges are using SLIM21 software.

Figure No.1

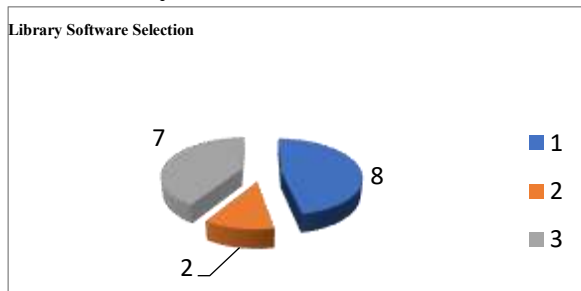


Who selected library software for your library?

Table No.1
Library Software Selection

Sr. No	Software Selection by	No. of Colleges
1	Library committee	08
2	Principal's Recommendation	02
3	Librarian	07
4	Any other	0

Figure No 2
Library Software Selection



Is demonstration facility available?

Table No.2
Availability of demonstration of Library Software

Sr. No	Demonstration	No. of Libraries	Percentage
1	Yes	12	85.71 %
2	No	1	7.14%
3	Not mentioned	1	7.14%
Total		14	100

Figure No.3

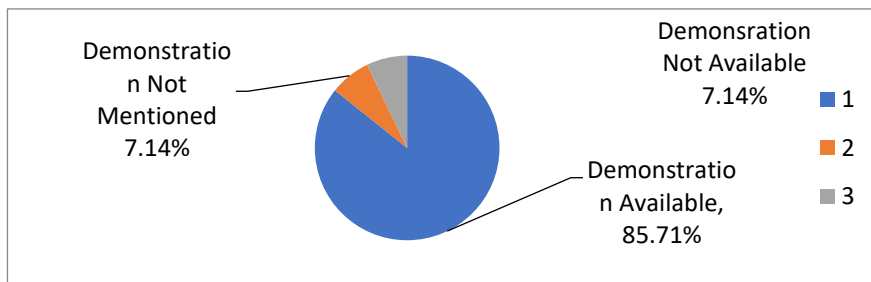


Table No. 3
SLIM21 and KOHA Availability of Demonstration

Sr. No	Software	Libraries	Yes	No	Not Responded
1	SLIM21	09	100%	0%	0%
2	KOHA	5	60%	20%	20%
Total		14	85.71%	7.14%	7.14%

Is library Software Company providing training to library professionals?

Table No.4
Availability of Software Training facility

Sr. No	Software Training	No of Libraries	Percentage
1	Yes	9	64 %
2	No	5	36%
Total		14	100 %

Above table describes nine, (64 %) Librarians got software training against that five (36%) Librarians are not trained.

Figure No. 4
Availability of Software Training facility

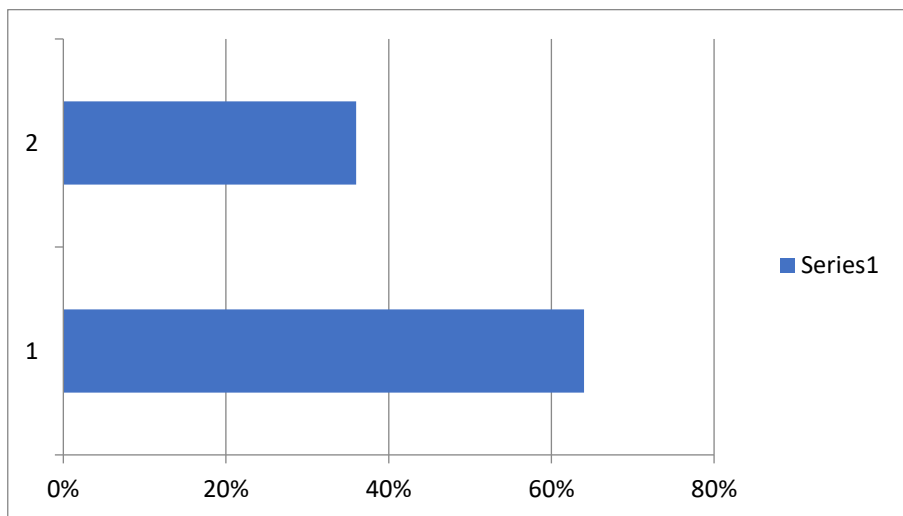


Table No.5
SLIM21 and KOHA availability of Training facility

Sr. No	Software	Libraries	Yes	No
1	SLIM21	09	88.88%	11.11%
2	KOHA	5	20%	80%
Total		14	64.28%	35,71%

Figure No.5
SLIM21 and KOHA availability of Software Training facility

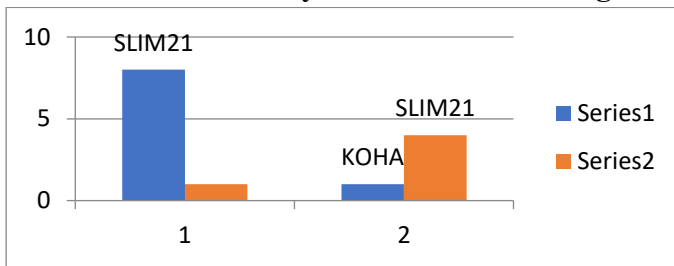


Table No.6
Availability of Software Manual

Sr. No	Software Manual	No. of Libraries	Percentage
1	Yes	11	78.57 %
2	No	3	21.43 %
Total		14	100%

Figure No.6
Availability of Software Manual

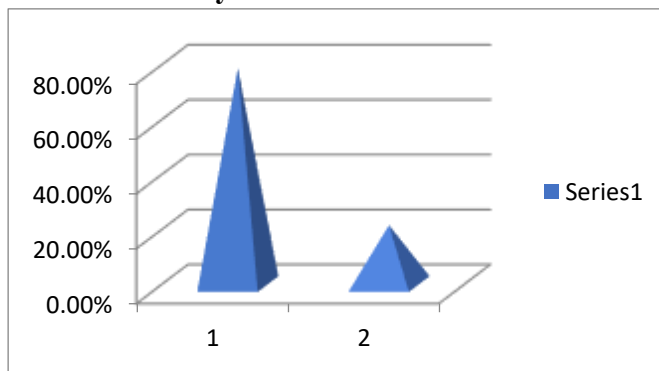


Table No.7
SLIM21 and KOHA Availability of Software manual

Sr. No	Software	Libraries	Yes	No	Not Responded
1	SLIM21	09	100%	0	0
2	KOHA	5	60%	20%	20%
Total		14	85.71	7.14%	7.14% ¹

Table No.8
Maintenance and support facility for Library software

Sr. No	Maintenance and Support	No. of Libraries	Percentage
1	Yes	12	85.72%
2	No	02	14.28%
Total		14	100%

Table No.9
SLIM21 and KOHA Maintenance and support facility

Sr. No	Software	TOTAL Libraries	Yes	No	Not Responded
1	SLIM21	09	100%	0%	0%
2	KOHA	5	40%	40%	20%
Total		14	140%	40%	20%

Table No 10
Availability of multi-language facility

Sr. No	Multilanguage	No. of Libraries	Percentage
1	Yes	13	92.85%
3	No	1	7.15%
Total		14	100%%

Table No .11

SLIM and KOHA Availability of multi-language facility

Sr. No	Software	Libraries	Yes	No	Total percentage
1	SLIM21	09	100%	0%	100%
2	KOHA	5	80%	20%	100%
Total		14	92.85%	7.14%	100%

Table No.12

Availability of User Group

Sr. No	Software User Group	No. of Libraries	Percentage
1	Yes	8	57.14%
2	No	4	28.57%
3	No Response	2	14.28%
Total		14	100%

Table No.13

Sr. No	Software	Libraries	Yes	No	No Response	Total
1	SLIM21	09	44.44%	44.44%	11.11	100%
2	KOHA	5	80%	0%	20%	100%
Total		14	57.14%	28.57%	14.28%	100%

SLIM21 and KOHA availability of Software User Group

Above table explains that SLIM21 (44.44%) libraries are having user group for the Library Software. SLIM21 (44.44%) libraries don't having user group for the Library Software. and SLIM21 (11.11%) libraries not responded this question. KOHA (80%) Libraries having user group and (20%) Libraries not responded this question.

6. Findings

1. All academic Institutes / Colleges can save the money of parent organization by using KOHA opensource software for Library and Information Management.

2. Library software's KOHA and SLIM21 demonstration is very essential for the implementation in Libraries.
3. Library Software training is very essential for the all-Library staff.
4. Academic Institutions must organize regularly workshops, training programs on Library software packages.

7. Conclusion

Software Companies are developing Library software packages for Library Automation; only few software companies are using advanced technology in Library software Package. KOHA is a very good library software package for all the libraries. SLIM21 is used by all types' college Libraries. If we compare overall performance of SLIM21 and KOHA, KOHA is very good Software, and SLIM21 is satisfactory and good.

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