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Role of Linear Algebra in Artificial Intelligence: Online survey Method

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Abstract:

The present study focuses on understanding the close relationship between Linear Algebra and Artificial Intelligence and highlighting the crucial Role Linear Algebra plays in the development and functioning of AI Technologies. Artificial Intelligence as an emerging and rapidly growing field relies heavily on Linear Algebra concepts such as Eigen value, Eigen vector, Vectors, Matrices, and etc. These Mathematical foundations enable machines to learn from data recognize patterns, make predictions and solve complex problems. In this study descriptive and analytical research methods is used. Primary data is collected through and online survey using a structured questionnaire. The collected data was analyzed using simple statistical tools and graphical presentation such as table and graphs this analysis will help to understand people's awareness and opinions about the Role of Linear Algebra in Artificial Intelligence. The study aims to clearly show the importance of Linear Algebra in AI education and research to contribute to academic discussion on the topic.

Keywords: Linear Algebra, Eigen values, matrices, artificial intelligence

1. Introduction

Artificial Intelligence (AI) is increasingly asserted to be a transformative force in the domains of Educational Technology, Management Sciences, and Operational Research. Intelligence is conventionally understood as the capacity to acquire, integrate, and apply knowledge for the resolution of complex problems. In the foreseeable future, intelligent machines are expected to substitute or augment human capabilities across numerous functional areas. Artificial Intelligence constitutes the systematic study of intelligent machines and software systems capable of reasoning, learning, acquiring knowledge, communicating, manipulating objects, and perceiving their environment. The term "Artificial Intelligence" was introduced by John McCarthy in 1956, defining it as a branch of computer science dedicated to enabling machines to exhibit behaviors analogous to human intelligence. AI fundamentally involves the study of computational processes that facilitate perception, reasoning, and action.

Artificial Intelligence is distinct from psychology due to its primary emphasis on computational mechanisms, and it diverges from traditional computer science owing to its focus on perception, reasoning, and autonomous action rather than mere algorithmic efficiency. By embedding intelligence into machines, AI significantly enhances their functionality, adaptability, and utility. AI systems operate through artificial neurons organized in artificial neural networks, alongside formal logical frameworks such as if–then rules and symbolic reasoning.

AI technologies have now reached a level of maturity that enables them to deliver substantial and tangible benefits across a wide spectrum of applications. The principal areas of Artificial Intelligence include Expert Systems, Intelligent Computer-Aided Instruction, Natural Language Processing, Speech Understanding, Robotics and Sensory Systems, Computer Vision and Scene

Recognition, and Neural Computing. Among these, expert systems represent one of the fastest-growing AI technologies, exerting a profound and far-reaching impact on diverse spheres of human life. The core techniques employed in Artificial Intelligence encompass Neural Networks, Fuzzy Logic, Evolutionary Computing, Computer-Aided Instruction, and Hybrid Artificial Intelligence systems that integrate multiple methodologies. AI is formally defined as the science and engineering of constructing intelligent machines, particularly intelligent computer programs. While it is closely related to the endeavor of using computers to model and understand human intelligence, Artificial Intelligence is not restricted to biologically inspired methods alone. Although no universally accepted definition of Artificial Intelligence exists, it is broadly characterized as the study of computational systems that enable perception, reasoning, learning, and purposeful action. In the contemporary digital era, the volume of data generated by both humans and machines vastly exceeds human cognitive capacity to assimilate, interpret, and make complex decisions based on such data. Consequently, Artificial Intelligence has emerged as the foundational framework for machine learning and is poised to become the cornerstone of future complex decision-making processes.

This paper critically examines the fundamental features of Artificial Intelligence, encompassing its conceptual introduction, definitions, historical evolution, applications, growth trajectory, and significant achievements.

2. Literature Review

The rapid advancement of AI has significantly increased the importance of Mathematical foundations, particularly linear algebra numerous researcher has emphasized that Linear Algebra forms the computational and conceptual backbone of AI system, enabling efficient data representation, transforming and learning.

- Olver and Shakiban (2006) [1] explored applied Linear Algebra with a strong emphasis on real world applications, including computational modeling and data analysis. Their work showed that Eigen values and Eigen Vectors play a crucial role in dimensionality reduction techniques such as Principal Component Analysis (PCA) which is extensively used in AI for feature extraction and noise reduction.
- Gentle (2007) [2] provided a comprehensive explanations of Matrix Algebra and its applications in statistical computing. His research demonstrated how systems of Linear Equations Matrix Decompositions and numerical stability are critical for regression analysis and AI based optimization tasks. These principles continue to be widely applied in modern AI system.
- Strang (2009) [3] demonstrates how Vectors, Matrices, Eigen values and matrix decompositions enable efficient data representation and transformation.
- Goodfellow, and Courville, (2016) [4] argue that deep neural network is essentially composition of Linear Transformations followed by non-linear activation function, making Linear Algebra indispensable for understanding and implementing deep learning architectures.
- Skansi (2018) [5] discussed the evolution of deep learning from logical calculus to modern AI systems. The author emphasized that deep neural networks rely heavily on Linear Algebra operation such as matrix multiplication, vector transformation, and back propagation algorithms for training and inference process.
- Browlee (2018) [6] focused on making Linear Algebra concepts accessible for machine learning practitioners. His work emphasized the practical application of Vectors and Matrices in neural networks, gradient descent and model optimization. The study underscored that Matrix multiplications and transformation are core operation in deep learning architecture.
- Aggarwal (2020) [7] highlighted that Linear Algebra and optimization techniques are essential for developing scalable machine learning algorithms. According to author concepts, such as Vector Spaces, Matrix operations and Eigen value problems are fundamental to understanding supervised and unsupervised learning models, especially in high dimensional data analysis.

- Zhang (2020) [8] presented a matrix algebra centric approach to AI arguing that almost all AI algorithms can be expressed using linear algebraic formulations. The study reinforced the idea that advanced technique such as singular value decomposition and Eigen values decomposition improve computational efficiency and model performance in AI system.
- Hu and Qu (2020) [9] introduced the concept of generalized constraints in AI, highlighting new mathematical challenges that arise when prior knowledge is integrated into intelligent system. Their research emphasized the importance of mathematical structures for developing explainable and interpretable. AI models, which is increasingly important in ethical and transparent AI development.
- Thomson and Anderson (2021) [10] investigated the impact of big data on AI algorithms and noted that Linear Algebra enables efficient handling of large scale data sets their research demonstrated that scalable AI models depend on optimized Matrix computation and Linear Transformation to process massive volumes of data.
- Sarker (2022) [11] examined AI based modeling technique and identified Linear Algebra as a core mathematical tool behind intelligent and automated systems. The study emphasized that Matrix based representation are fundamental for pattern recognition clustering and predictive analytics across various AI applications.
- Meenu (2024) [12] reviewed the Role of core mathematical disciplines in AI and ML explaining how Linear Algebra supports data representation.

Overall, existing literature strongly supports the view that Linear Algebra is indispensable to Artificial Intelligence. Previous studies have consistency demonstrated its Role in Machine learning, deep learning optimization and data driven decision making. However, there remains a need for integrated research that connects theoretical Linear Algebra concepts with emerging AI domains such as Quantum computing, explainable AI and intelligent automation which are area this paper seeks to emphasize and expand upon.

3. Case and Methodology

Relationship between Linear Algebra and Artificial Intelligence

Linear algebra is considered the foundational framework for the development of Artificial Intelligence (AI). Linear Algebra constitutes of fundamental branch of mathematics that underpins the theoretical and computational framework of AI. It serves as the backbone of numerous machine learning and deep learning algorithms by providing structured methods for data representation and transformation. Core concept of linear algebra such as Vectors, Matrices, Eigen values, Eigen Vectors and Linear Transformations are extensively employer to make store and manipulate high dimensional data with in AI system. Given the contemporary applications frequently operate on massive datasets, Linear Algebra offers effective and scalable tools enable effective computation dimensionality reduction and feature extraction.

Research Design:

Significance of the study:

Linear algebra provides the basic mathematical framework for artificial intelligence models through vectors, matrices, and linear transformations. High-dimensional data in AI is efficiently represented and processed using matrices and vector spaces. Linear algebra techniques reduce data complexity while preserving essential information, improving model performance. The study strengthens theoretical understanding and practical application of AI for students and researchers.

Objectives of the study:

- To examine the application of Matrices, Vectors, Eigenvalues and Eigenvectors in Artificial Intelligence.

• The objective of this is today is to analyse the contribution of Linear Algebra to the theoretical and practical framework of AI.

Scope of the study:

The study focuses on understanding the basic concepts of linear algebra used in artificial intelligence. It includes the application of matrices and vectors in AI and machine learning models. The study explains the role of linear algebra in handling large datasets.

Research Methodology

• Participants

The sample will consist of UG, PG and some from other categories.

• Instruments

Data of students was collected with the help of questionnaire on Role of Linear Algebra in Artificial Intelligence. The tool will include both closed and open items.

• Procedure

Before data collection, good Rapport was established with the students and their safety was ensured. To collect data, a questionnaire of 20 questions was created and then we converted it into google form. Through internet and WhatsApp, it was send to students group. The language of questions was kept simple and readable by everyone. With the help of google form we received responses.

Sampling Technique

Survey Method

Hypothesis Testing

The chi-square test is adopted for the most part alludes to Pearson`s chi-square and is otherwise called the chi-square decency of fit test or the chi-square test for freedom. We utilize this test when we have two all-out factors and need to decide if there is a critical relationship between the two factors.

a) Sample frame – 125

b) Sample size – 108

c)Sampling method – Random sampling method

Hypothesis

Theory are the proposed suspicion to be demonstrated or opposed by the examination discoveries. An exploration examine comprises of two speculation i.e. invalid theory and elective speculation. For the above required objectives the following hypothesis testing were done.

Hypothesis -A

H_0: The knowledge of Linear Algebra did not improved student performance in the application of AI.

H_1: The knowledge of Linear Algebra improved student performance in the application of AI.

Particulars	No. Of responses	Percentage
Yes	99	91.67%
No	9	8.33%
Total	108	100%

S.No.	O_i	E_i	$O_i - E_i$	$(O_i - E_i)^2$	$(O_i - E_i)^2/E_i$
1.	99	54	45	2025	37.5
2.	9	54	-45	2025	37.5
Total	108	108	0		75.0

Calculated Value =75.0 Tabulated Value=3.841

Degree of freedom = 2-1=1

Thus null hypothesis is rejected and we can accept the internal hypothesis i.e. 'H_1'.

Conclusion:

The computed value of Chi square is 75.0. The table value of Chi square is 3.841, since the ascertained value is more than the table value of Chi square. Along these lines, H_0 (Null Hypothesis) is rejected and H_1 (Alternative Hypothesis) is concluded i.e. Linear Algebra knowledge improves students' performance in AI.

Hypothesis -B
H0: Matrices do not help in handling large data set in AI models.
H1: Matrices help in handling large data sets in AI models.

Particulars	No. Of Responses	Percentage
Yes	96	88.89%
No	12	11.11%
Total	108	100%

S.No.	O_i	E_i	$O_i - E_i$	$(O_i - E_i)^2$	$(O_i - E_i)^2/E_i$
1.	96	54	42	1764	32.67
2.	12	54	-42	1764	32.67
Total	108	108	0		65.34

Calculated Value = 65.34 Tabulated Value = 3.841

Degree of freedom = 2-1=1

Thus null hypothesis is rejected and we can accept the internal hypothesis i.e. 'H_1'.

Conclusion:
The computed value of Chi square is 65.34. The table value of Chi square is 3.841, since the ascertained value is more than the table value of Chi square. Along these lines, H_0 (Null Hypothesis) is rejected and H1 (Alternative Hypothesis) is concluded i.e. Matrices powers large-data handling in AI.

Hypothesis -C
H_0: Eigenvalue and Eigenvectors do not help in understanding data patterns in AI models.
H_1: Eigenvalues and Eigenvectors help in understanding data patterns in AI models.

Particulars	No. of Responses	Percentage
Yes	96	88.89%
No	12	11.11%
Total	108	100%

S.No.	O_i	E_i	$O_i - E_i$	$(O_i - E_i)^2$	$(O_i - E_i)^2/E_i$
1.	96	54	42	1764	32.67
2.	12	54	-42	1764	32.67
Total	108	108	0		65.34

Calculated Value = 65.34 Tabulated Value = 3.841

Degree of freedom = 2-1=1

Thus null hypothesis is rejected and we can accept the internal hypothesis i.e. 'H_1'.

Conclusion:
The computed value of Chi square is 65.34. The table value of Chi square is 3.841, since the ascertained

value is more than the table value of Chi square. Along these lines, H_0 (Null Hypothesis) is rejected and H_1 (Alternative Hypothesis) is concluded i.e. Eigenvalues and Eigenvectors reveal data structure.

Hypothesis-D
H0: AI does not help students learn Linear Algebra easily.
H1: AI help students learn Linear Algebra easily.

Particulars	No. Of Responses	Percentage
Yes	95	87.96%
No	13	12.04%
Total	108	100%

S.No.	O_i	E_i	$O_i - E_i$	$(O_i - E_i)^2$	$(O_i - E_i)^2/E_i$
1.	95	54	41	1681	31.13
2.	13	54	-41	1681	31.13
Total	108	108	0		62.26

Calculated Value = 62.26 Tabulated Value = 3.841

Degree of freedom = 2-1=1

Thus null hypothesis is rejected and we can accept the internal hypothesis i.e. 'H_1'.

Conclusion:

The computed value of Chi square is 65.26. The table value of Chi square is 3.841, since the ascertained value is more than the table value of Chi square. Along these lines, H_0 (Null Hypothesis) is rejected and H_1 (Alternative Hypothesis) is concluded i.e. AI makes learning linear algebra easy.

4. Limitations

- **High Cost and Time Consumption:** The collection of primary data is constrained by high financial cost and prolong time requirement which constitute a major limitation of this method.
- **Response Bias:** Responses that are generated are neither completely genuine not fake, its left to one`s conscience. i.e. participants bias is an issue.
- **Generalization of Result:** Findings may not be applicable to students from different cultural, educational, or socio-economic backgrounds.

5. Findings

- Majority of participants acknowledged that the knowledge of Linear Algebra improved student performance in the application of AI.
- The majority of participants admitted that Matrices help in handling large data sets in AI.
- The majority of students reported that Eigenvalues and Eigenvectors help in understanding data patterns in AI models.
- The majority of participants agreed that AI help students learn Linear Algebra easily.

6. Conclusion

- A majority of students stated that a strong understanding of Linear Algebra significantly enhances students' performance in the application of Artificial Intelligence. Students with sound knowledge of Linear Algebra concepts are better able to comprehend AI models, analyse data structures, and apply mathematical techniques effectively, which leads to improved learning outcomes and overall efficiency in AI-based problem solving.
- Matrices play a crucial role in handling and managing large datasets in Artificial Intelligence. A proper understanding of matrix operations enables students to efficiently organize, process,

and analyse high-dimensional data, which is essential for the effective functioning and scalability of AI models.

- Eigenvalues and eigenvectors play a crucial role in revealing hidden patterns within data used by AI models. They help identify the most important directions in which data varies, allowing models to focus on meaningful features while reducing noise. Through techniques like dimensionality reduction and feature extraction, eigenvalues indicate the significance of each pattern, and eigenvectors define the direction of these patterns. As a result, AI models become more efficient, accurate, and capable of understanding complex data structures, leading to better prediction, classification, and decision-making performance.
- Artificial Intelligence plays a supportive and effective role in making the learning of Linear Algebra more accessible for students. AI-based tools, such as intelligent tutoring systems, visual simulations, and adaptive learning platforms, help students understand complex concepts more clearly, reduce learning difficulties, and improve overall engagement with the subject.

Disclosure Statement
The authors are greatly honored by the use of results published earlier which helped us to complete the present study.

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