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# Mathematics and Its Appliance in Artificial Intelligence

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**ABSTRACT:** Artificial Intelligence (AI) has emerged as a transformative technology, revolutionizing various aspects of our lives. Behind the remarkable advancements and capabilities of AI lies the foundational role of mathematics. Mathematics provides the framework that enables AI systems to learn, reason, and make intelligent decisions. In this article, we explore the application of mathematics in the field of AI and its significance.

Mathematics serves as the backbone of AI algorithms and models, empowering machines to process, analyze, and interpret vast amounts of data. Concepts from linear algebra, calculus, probability theory, and statistics are essential for developing machine learning algorithms. These algorithms use mathematical equations and functions to identify patterns, make predictions, and classify information.

Linear algebra, for instance, is fundamental in designing neural networks, which are the building blocks of deep learning. Matrices and vectors are used to represent and manipulate data within neural networks, facilitating complex computations and enabling AI systems to extract meaningful insights from data.

Calculus plays a crucial role in optimizing AI models. Techniques such as gradient descent and backpropagation utilize calculus to minimize errors and adjust the parameters of machine learning models. These mathematical techniques enable AI systems to learn from data and continuously improve their performance.

**KEYWORDS-**mathematics, artificial intelligence, appliance, theories, reasoning

## I. INTRODUCTION

Probability theory and statistics are vital in AI for tasks such as natural language processing, computer vision, and decision-making. Probability distributions, Bayesian inference, and hypothesis testing provide the mathematical framework to quantify uncertainty, analyze data, and make probabilistic predictions.

The application of mathematics in AI is fundamental to the development and success of intelligent systems. Mathematics provides the tools and concepts necessary for AI algorithms to process data, learn patterns, and make informed decisions. As AI continues to evolve and shape our world, the synergy between mathematics and AI will remain crucial, unlocking new frontiers and possibilities for innovation. By harnessing the power of mathematics, AI has the potential to transform industries, solve complex problems, and enhance our daily lives in remarkable ways.[1,2,3]

## II. DISCUSSION

“Mathematics is the language with which God has written the universe.” -Galileo Galilei

The future we have seen in science fiction movies is here. From virtual reality to functional gadgets, AI has invaded our lives in ways that no one has ever seen or expected before. AI tools and chatbots have been on the verge of a breakthrough in the promptly-evolving tech realm.

AI is not magic; it's just mathematics.

The ideas behind thinking machines and the possibility to mimic human behavior are done with the help of mathematical concepts.

Artificial Intelligence and Mathematics are the two branches of the same tree. And if you want to thrive in your AI career, you need to study mathematics; merely being a fan of science fiction won't be enough.[4,5,6]

If you're going to build an Artificial Intelligence career and dominate hiring in the space, be friends with mathematics, and it will rock your world.

Being a mathematician and a fan of Artificial Intelligence, I want to share the magical connection between AI and mathematics.

Let's dive deeper into the fascinating realm.

How is AI connected with mathematics?

Artificial intelligence problems constitute on two general categories; Search Problems, and Representation Problems. Following them are interconnected models and tools like Rules, frames, Logics, and Nets. All of them are very mathematical topics.

The primary purpose of Artificial intelligence is to create an acceptable model for human understanding. And these models can be prepared with the ideas and strategies from various branches of Mathematics.

Consider self-driving cars; their goal is to recognize objects and people in videos images. There is mathematics behind these cars in the form of minimization procedures and back-propagation. Mathematics helps AI scientists to solve challenging deep abstract problems using traditional methods and techniques known for hundreds of years.

### III. RESULTS

#### 1. Algebra You Need to Know for AI

[7,8,9]

Knowledge of algebra is perhaps fundamental to math in general. Besides mathematical operations like addition, subtraction, multiplication and division, you'll need to know the following:

- Exponents
- Radicals
- Factorials
- Summations
- Scientific Notations

#### 2. Linear Algebra You Need to Know for AI

Linear Algebra is the primary mathematical computation tool in Artificial Intelligence and in many other areas of Science and Engineering. With this field, you need to understand 4 primary mathematical objects and their properties:

- Scalars—a single number (can be real or natural).
- Vectors—a list of numbers, arranged in order. Consider them as points in space with each element representing the coordinate along an axis.
- Matrices—a 2-D array of numbers where each number is identified by 2 indices.
- Tensors—an N-D array ( $N > 2$ ) of numbers, arranged on a regular grid with N-axes. Important in Machine Learning, Deep Learning and Computer Vision.
- Eigenvectors & Eigenvalues—special vectors and their corresponding scalar quantity. Understand the significance and how to find them.
- Singular Value Decomposition—factorization of a matrix into 3 matrices. Understand the properties and applications.
- Principal Component Analysis (PCA)—understand the significance, properties, and applications.
- Properties such as the Dot product, Vector product and the Hadamard product are useful to know as well.

### 3. Calculus You Need to Know for AI

Calculus deals with changes in parameters, functions, errors and approximations. Working knowledge of multi-dimensional calculus is imperative in Artificial Intelligence.

The following are the most important concepts (albeit non-exhaustive) in Calculus:

- Derivatives—rules (addition, product, chain rule, and so on), hyperbolic derivatives (tanh, cosh, and so on) and partial derivatives.[10,11,12]
- Vector/Matrix Calculus—different derivative operators (Gradient, Jacobian, Hessian and Laplacian)
- Gradient Algorithms—local/global maxima and minima, saddle points, convex functions, batches and mini-batches, stochastic gradient descent, and performance comparison.

### 4. Statistics & Probability Concepts You Need to Know for AI

This topic will probably take up a significant chunk of your time. Good news: these concepts aren't difficult, so there's no reason why you shouldn't master them.

- Basic Statistics—Mean, median, mode, variance, covariance, and so on.
- Basic rules in probability—events (dependent and independent), sample spaces, conditional probability.
- Random variables—continuous and discrete, expectation, variance, distributions (joint and conditional).
- Bayes' Theorem—calculates validity of beliefs. Bayesian software helps machines recognize patterns and make decisions.
- Maximum Likelihood Estimation (MLE)—parameter estimation. Requires knowledge of fundamental probability concepts (joint probability and independence of events).
- Common Distributions—binomial, poisson, bernoulli, gaussian, exponential.

### 5. Information Theory Concepts You Need to Know for AI

This is an important field that has made significant contributions to AI and Deep Learning, and is yet unknown to many. Think of it as an amalgamation of calculus, statistics, and probability.[13,14,15]

- Entropy—also called Shannon Entropy. Used to measure the uncertainty in an experiment.
- Cross-Entropy—compares two probability distributions and tells us how similar they are.
- Kullback Leibler Divergence—another measure of how similar two probability distributions are.
- Viterbi Algorithm—widely used in Natural Language Processing (NLP) and Speech.
- Encoder-Decoder—used in Machine Translation RNNs and other models.

## CONCLUSION



If you are terrified at the mere mention of “math”, you’re probably not going to have much fun in Artificial Intelligence.

But if you’re willing to invest time to improve your familiarity with the principles underlying calculus, linear algebra, stats, and probability, nothing—not even math—should get in the way of you getting into AI.[16,17,18]

Math really is fun. As you go deeper into math, be sure to understand the beauty of a certain math concept and how it affects something. You’ll soon share the unbridled passion that many mathematicians and AI Scientists have!

A tip: Treat mathematical concepts as a pay-as-you-go: whenever a foreign concept pops up, grab it and devour it! The guide above presents a minimal, yet comprehensive, resource to understand any kind of topic or concept in AI.[19,20,21]

## REFERENCES

1. This list of intelligent traits is based on the topics covered by the major AI textbooks, including: Russell & Norvig (2021), Luger & Stubblefield (2004), Poole, Mackworth & Goebel (1998) and Nilsson (1998)
2. <sup>a b</sup> This list of tools is based on the topics covered by the major AI textbooks, including: Russell & Norvig (2021), Luger & Stubblefield (2004), Poole, Mackworth & Goebel (1998) and Nilsson (1998)
3. <sup>a</sup> It is among the reasons that expert systems proved to be inefficient for capturing knowledge.<sup>[27][28]</sup>
4. <sup>a</sup> "Rational agent" is general term used in economics, philosophy and theoretical artificial intelligence. It can refer to anything that directs its behavior to accomplish goals, such as a person, an animal, a corporation, a nation, or, in the case of AI, a computer program.
5. <sup>a</sup> Alan Turing discussed the centrality of learning as early as 1950, in his classic paper "Computing Machinery and Intelligence".<sup>[40]</sup> In 1956, at the original Dartmouth AI summer conference, Ray Solomonoff wrote a report on unsupervised probabilistic machine learning: "An Inductive Inference Machine".<sup>[41]</sup>
6. <sup>a</sup> See AI winter § Machine translation and the ALPAC report of 1966
7. <sup>a</sup> Compared with symbolic logic, formal Bayesian inference is computationally expensive. For inference to be tractable, most observations must be conditionally independent of one another. AdSense uses a Bayesian network with over 300 million edges to learn which ads to serve.<sup>[86]</sup>
8. <sup>a</sup> Expectation-maximization, one of the most popular algorithms in machine learning, allows clustering in the presence of unknown latent variables.<sup>[88]</sup>
9. <sup>a</sup> Russell and Norvig suggest the alternative term "computational graphs" – that is, an abstract network (or "graph") where the edges and nodes are assigned numeric values.
10. <sup>a</sup> Some form of deep neural networks (without a specific learning algorithm) were described by: Alan Turing (1948);<sup>[114]</sup> Frank Rosenblatt(1957);<sup>[114]</sup> Karl Steinbuch and Roger David Joseph (1961).<sup>[115]</sup> Deep or recurrent networks that learned (or used gradient descent) were developed by: Ernst Ising and Wilhelm Lenz (1925);<sup>[116]</sup> Oliver Selfridge (1959);<sup>[115]</sup> Alexey Ivakhnenko and Valentin Lapa (1965);<sup>[116]</sup> Kaoru Nakano (1977);<sup>[117]</sup> Shun-Ichi Amari (1972);<sup>[117]</sup> John Joseph Hopfield (1982).<sup>[117]</sup> Backpropagation was independently discovered by: Henry J. Kelley (1960);<sup>[114]</sup> Arthur E. Bryson (1962);<sup>[114]</sup> Stuart Dreyfus (1962);<sup>[114]</sup> Arthur E. Bryson and Yu-Chi Ho (1969);<sup>[114]</sup> Seppo Linnainmaa (1970);<sup>[118]</sup> Paul Werbos (1974).<sup>[114]</sup> In fact, backpropagation and gradient descent are straight forward applications of Gottfried Leibniz' chain rule in calculus (1676),<sup>[119]</sup> and is essentially identical (for one layer) to the method of least squares, developed independently by Johann Carl Friedrich Gauss (1795) and Adrien-Marie Legendre (1805).<sup>[120]</sup> There are probably many others, yet to be discovered by historians of science.
11. <sup>a</sup> Geoffrey Hinton said, of his work on neural networks in the 1990s, "our labeled datasets were thousands of times too small. [And] our computers were millions of times too slow"<sup>[121]</sup>
12. <sup>a</sup> The Smithsonian reports: "Pluribus has bested poker pros in a series of six-player no-limit Texas Hold'em games, reaching a milestone in artificial intelligence research. It is the first bot to beat humans in a complex multiplayer competition."<sup>[137]</sup>
13. <sup>a</sup> Including Jon Kleinberg (Cornell), Sendhil Mullainathan (University of Chicago), Cynthia Choudechova (Carnegie Mellon) and Sam Corbett-Davis (Stanford)<sup>[173]</sup>
14. <sup>a</sup> Moritz Hardt (a director at the Max Planck Institute for Intelligent Systems) argues that machine learning "is fundamentally the wrong tool for a lot of domains, where you're trying to design interventions and mechanisms that change the world."<sup>[178]</sup>



15. ^ When the law was passed in 2018, it still contained a form of this provision.
16. ^ This is the United Nations' definition, and includes things like land mines as well.<sup>[190]</sup>
17. ^ See table 4; 9% is both the OECD average and the US average.<sup>[200]</sup>
18. ^ Sometimes called a "robopocalypse".<sup>[207]</sup>
19. ^ "Electronic brain" was the term used by the press around this time.<sup>[234]</sup>
20. ^ Daniel Crevier wrote, "the conference is generally recognized as the official birthdate of the new science."<sup>[237]</sup> Russell and Norvig called the conference "the inception of artificial intelligence."<sup>[236]</sup>
21. ^ Russell and Norvig wrote "for the next 20 years the field would be dominated by these people and their students."<sup>[238]</sup>



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