Journal of Analysis and Computation (JAC)
(An International Peer Reviewed Journal), www.ijaconline.com, ISSN 0973-2861
Volume XVII, Issue I, Jan-June 2023

APPLICATION OF MATHEMATICS IN MACHINE LEARNING: A REVIEW

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ABSTRACT

Machine Learning has emerged as a powerful tool for extracting meaningful insights and making predictions from large datasets. Machine Learning Algorithms largely rely on Mathematical Principles for building Models, uncovering patterns, and making accurate predictions. This research paper discusses the role of mathematics in various Machine Learning algorithms and Models. It highlights how various branches of Mathematics work hand in hand to develop useful machine learning algorithms.

Keywords: Machine Learning, mathematics, algorithms, models, statistics, probability, linear algebra, calculus, optimization.

1. INTRODUCTION

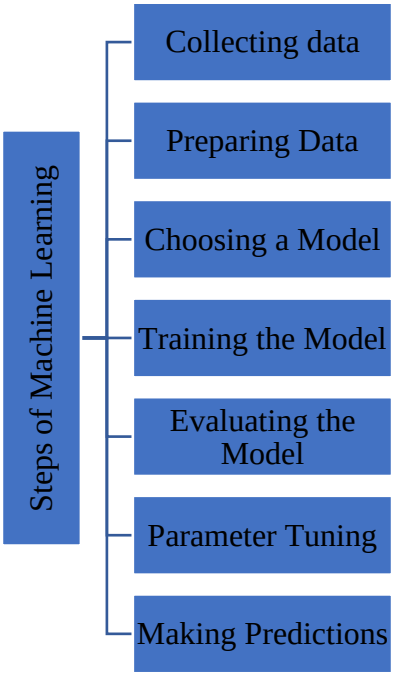
Machine learning is about automatically extracting valuable information from data by designing algorithms. The emphasis here is on "automatic," i.e., machine learning is concerned with general-purpose methodologies that can be applied to many datasets, while producing meaningful results. There are three core concepts in machine learning: data, a model, and learning. Since machine learning is inherently data-driven, the goal is to design general-purpose methodologies that can extract valuable patterns from data, ideally without requiring extensive domain-specific expertise. As machine learning is applied to new domains, developers need to develop new methods and

extend existing algorithms. Understanding the mathematical basis of machine learning and uncovering relationships between different tasks is essential.

2. Machine Learning Processing

Machine learning involves designing algorithms that enable systems to learn and improve themselves through specific programming. The goal is to develop algorithms that can automatically gather data, learn from it, and make informed decisions. Machine learning aims to make systems think and act like humans, exhibiting human-like intelligence.

Steps of Machine Learning Process



3. Mathematics Behind Machine Learning:

3.1. Statistics and Probability

Statistics and Probability play a crucial role in data analytics and are widely used in machine learning. They are employed for data analysis, visualization, interpretation, and discovering insights. Techniques from statistics and probability theory are utilized for collecting, preprocessing, and manipulating data. Key topics include descriptive statistics, hypothesis testing, regression analysis, probability distributions, conditional probability, sampling, central limit theorem, and Bayes' theorem.

3.2. Linear Algebra

Linear algebra concepts are pervasive in machine learning. It is a foundational skill required to become proficient in machine learning. Understanding linear algebra is essential to comprehend how algorithms work. Concepts such as working with vectors, matrix operations in n-dimensional space, matrix properties, matrix transpose and inverse, determinants, dot product, eigenvalues and eigenvectors, matrix factorization, principal component analysis, and orthogonality are important.

3.3 Calculus

Calculus knowledge is crucial for understanding various machine learning applications. It is necessary to have a good grasp of differential and integral calculus, limits, continuity, partial derivatives, functions such as step, sigmoid, logit, and ReLU functions, finding maxima and minima of a function, and using product and chain rules. Multivariable calculus is particularly important when dealing with datasets having multiple feature variables.

3.4. Optimization

Almost all machine learning algorithms can be formulated as optimization problems aiming to find the extremum of an objective function. Building models and constructing suitable objective functions are the initial steps in machine learning methods. Once the objective function is defined, appropriate numerical or analytical optimization methods are employed to solve the optimization problem. Machine learning algorithms can be categorized into supervised learning, semi-

supervised learning, unsupervised learning, and reinforcement learning based on the modeling purpose and the problem being addressed.

3.5. Fractional Calculus

Fractional Calculus has played a vital role in recent years to solve various real-world problems dealing with nonlinear properties of complex problems.

The term fractional calculus was first used by l'Hopital in a letter written by him to Lebinitz, where he asked "what would happen if integer will be replaced by a fraction in a differential operator.

To which Lebinitz replied "It will lead to a paradox from which one day useful consequences will be drawn".

Machine Learning learns complex behavior from a Data set and Fractional Calculus uses memory of a system while creating models. Therefore, Fractional calculus plays an important role in Machine learning where fractional order of various processes are used to include the memory term. Stationarity is required when supervised machine learning algorithms are applied on financial time series data. In the process of creating a predictive model, it is assumed that a given time series is generated by a stochastic process.

4. Conclusion

In this review paper we have analyzed the application of mathematics in developing strong machine learning algorithms. How various branches of mathematics like calculus, statistics, linear algebra etc. play a vital role in making more accurate predictions using machine learning algorithms, are also discussed. Study of fractional calculus is also incorporated as a recent development in machine learning process, which increases the accuracy by involving memory in the modelling approach.

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