

Application of Artificial Intelligence Technologies in Concrete and Nanomaterials

Xiaoshuang Li *

Department of Engineering, University of Ottawa, Ottawa, Canada

* Corresponding Author Email: xli419@uottawa.ca

Abstract. With the continuous adjustment of contemporary technology, artificial intelligence has gradually become irreplaceable. The main goal of the paper is to discuss the core of artificial intelligence - machine learning and its application in basic concrete materials and nanomaterials. Concrete is a kind of mixed material with high hardness, high compressive strength, low cost and easy production; Nanomaterials, whose properties are mainly determined by quantum mechanics, consist of a powdery or agglomerated natural or artificial material composed of basic particles. With the continuous advancement of modern technology, machine learning algorithms are gradually replacing previous technical algorithms such as manual algorithms, and becoming a very important tool in the engineering field. However, with the increasing complexity of various new materials, some materials such as nanomaterials have still not fully mastered the application methods of machine learning data analysis, therefore they have some limitations on their use. In this work, the impact and role of machine learning on material applications are discussed. Data patterns learned by humans are entered into machine learning, and high-dimensional data are easier to analyze. Machine learning has brought the development of concrete and nanotechnology in the field of materials to a new level, and a new milestone has come for technology to replace labor.

Keywords: Artificial Intelligence; concrete materials; nanomaterials; machine learning.

1. Introduction

Artificial intelligence (AI) is a new technological science in modern times. [2] It is mainly used to study and try to extend the perception and reasoning of human intelligence and to explore and challenge the potential of human behavior and computing. At present, from the comprehensive analysis of various methods, machine learning is the most promising method in AI. It enables users to transfer large amounts of data to computer algorithms, and then let the computer analyze this data and make data-driven recommendations and decisions based on the input data. However, there are still some manually extracted raw data features in real life, such as photos of cars being recognized on the street, which are very simple for human beings to understand but very challenging for machines. Until the emergence of new research in the field of ML-deep learning, the limitations of machine learning began to be alleviated. Deep learning not only has the function of machine learning to input the data to the database, but also can analyze data into multiple levels. It can help machines to convert data features from simple to abstract like human beings and can recognize data such as images and sounds.

The continuous development of machine learning and deep learning gradually affects various materials in engineering fields. As one of the most widely used materials in today's society such as construction field, concrete interacts closely with human beings. Concrete is a classic mixed product made of different materials, and its application performance has been closely watched. Accurately predicting the properties of concrete has been a problem that is actively being sought in order to allow researchers to rely more reliably on the use of concrete mixtures. However, when collecting concrete sample models, the results obtained are often inaccurate due to the complex production conditions and mixing components of concrete. As a result of continuous exploration and research, the emergence of machine learning algorithms in AI has become the main solution to overcome inaccuracy. Machine learning can ensure that the application and quality of samples are strictly analyzed, so as to make the best decision. [3]

Not only concrete, a trending material, has been significantly developed through the advancement of AI, with the continuous innovation of technology, advanced atomic and molecular manufacturing substances such as nanomaterials have also been gradually affected and developed. However, the use of nanomaterials is still relatively low compared to other material sciences such as steel or concrete materials, which means that machine learning methods for expressing nanomaterial datasets still have great potential, but there are some limitations and no be widely used. The application of machine learning and deep learning focuses on nano-safety, explores current obstacles and feasible solutions, integrates more in-depth methods of AI, and mines s wider range of nanomaterial sources and biochemical space.

This paper discusses the core of AI - machine learning and its application in basic concrete materials and nanomaterials.

2. AI technologies

In the application of AI, intelligent algorithms, as a part of AI, are very helpful for practical applications in major engineering fields. Intelligent algorithms include two parts: machine learning and intelligent optimization algorithms. Since the last century, machine learning has been unprecedentedly active in the academic field through the development of various research paths and goals, and has become a new discipline. Intelligent optimization algorithms are mathematical models generated by simulating the different behaviors of biological individuals and groups in nature. The biggest advantage this generation method brings to the algorithm is that a single algorithm can be combined with other algorithms to form multiple hybrid types of algorithms. Currently, AI algorithms can effectively handle a variety of complex problems and multi-extreme value problems, active in practical engineering problems in multiple fields.

Machine learning is equivalent to a subset of A, which can access and analyze data and generate intelligent and practical insights. When machine learning was not yet widely used, the calculations and coding in the machine execution process needed to be executed accurately at each step to achieve the desired results. With the advent of machine learning, this limitation has been removed, and the same algorithms and code can be used for various modeling applications. Machine learning algorithms can already process higher dimensional data by imitating humans to learn data patterns. [1]

Among various traditional machine application methods, traditional machine learning is different from deep learning. Supervised learning and unsupervised learning are usually listed as the two main methods of machine learning. In supervised learning, machine learning models use computer algorithms to convert known data sets into patterns and hypotheses to predict future values. Machine learning technologies are mainly divided into four types, which are also the most commonly used and popular technologies: artificial neural networks (ANN), support vector machines (SVM), decision trees, and evolutionary algorithms (EA). It is important to note that the entry of different data sets and parameters may affect the selection of the model. So far, almost all computational models have used simple statistical methods.

As an important part of machine learning, deep learning is mainly based on machine learning and consists of more hidden layers and neural networks with complex structures. Due to its ability to recognize features through images, speech, etc., fields such as structural mechanics and material systems have been transformed. One of the main reasons why deep learning can produce leaps and bounds is not actually that it can generate accurate models, but it can automatically generate useful generators without requiring professional input into the modeling process. Convolutional neural networks (CNNs), autoencoders, and generative adversarial networks (GANs) are the most commonly used learning algorithms for deep learning. Among them, CNN is very useful in identifying image features generated by spatial correlation; ANN is the main method for learning local correlation of data; while the GAN method is not supervised, it consists of a generator and a discriminator, which can Compare and assess the quality of experimental models with known data.

3. Application of AI technologies in Concrete

3.1. Common AI technologies in concrete application

Due to the rapid development of the civil engineering industry, the requirements for concrete materials are also constantly increasing, which requires the generation of new concrete to meet the rapidly developing needs. In order to better meet the standards of design specifications, predicting the properties of concrete such as mechanical properties has become a very important research duty. Based on the complex relationship between concrete composition and production conditions, the results obtained by traditional models used to predict concrete properties are not accurate. In order to efficiently deal with these unresolved problems, researchers tried to use machine learning models to estimate the mechanical strength of concrete.

Different ANN algorithms are very common and practical in calculating concrete strength. ANN is inspired by analyzing the basic framework of the human brain. It is a nonlinear model. Therefore, the structure of the ANN method is also like the human brain framework, which is divided into three parts: input layer, hidden layer and output layer. It uses continuous learning algorithms to make the concept of the problem understood by the model. If the type of learning algorithm changes, the overall structure of the artificial neural network would also change. Some ANN methods for estimating concrete strength and some concrete types are discussed below.

Among many ANN methods, the backpropagation neural networks (BPNN) method is one of the most widely used. It is a multi-layer feedforward neural network that is generally trained based on the inaccuracy backpropagation algorithm. Cellular concrete is a typical example of using BNPP to obtain compressive strength. It is a special construction concrete made of Portland cement, sand, fly ash and other ingredients mixed in different dosages. The BNPP operation process is not cumbersome. When testing cellular concrete, the researcher only needs to enter some basic parameters such as cement, water-to-cement ratio, and sand-to-cement ratio, and it is easy to obtain the result of compressive strength. However, in this process, there are some basic model analysis errors, such as absolute average error and average algebraic error that cannot be avoided. Not only cellular concrete, but also different types of concrete with different compositions and different qualities such as HPC, RAC and even normal concrete can be achieved through BNPP to achieve compressive strength. Just a branch method in one of the main methods of machine learning can complete various property detection with high accuracy, which is enough to show that the impact of AI on concrete and even the entire basic material field is huge.

3.2. Practical applications of AI technologies in concrete

Due to the vigorous development and popularity of machine learning, researchers around the world are trying or have successfully applied machine learning algorithms to the use of concrete technology.

Scholars from Canadian universities used an ANN model based on machine learning to predict the compressive strength of geopolymer concrete using fly ash and bottom ash instead of fine aggregate. They designed 14 training algorithms in back propagation, the number of hidden layers and the nodes of each layer. Neural network models that differ in the number of neurons. The prediction performance of the models was analyzed and compared using the mean square error and correlation coefficient, and a Bayesian regularized neural network model with higher accuracy for the compressive strength of fly ash and bottom ash base polymer concrete was established. [4] [5] [6]

Researchers from the University of Birmingham in the UK used artificial neural networks to predict the mechanical properties of waste rubber environmentally friendly concrete, such as 7-day compressive strength and 28-day compressive strength, and used Levenberg-Marquardt and Bayesian regularization and scale sharing. These three algorithms, yoke gradient, determine the optimal neural network structure. The mean square error and coefficient of determination are a relatively accurate and convenient method to evaluate the performance of the optimal artificial neural network structure. The prediction accuracy of the artificial neural network prediction model and multiple linear regression can also be compared.

In addition, scholars from China proposed a fuzzy mean clustering algorithm optimized by combining two AI algorithms, genetic algorithm and simulated annealing algorithm, to analyze the clustering of compression test data of large-volume concrete cube test blocks. In this way, a concrete cube test block compressive strength test data estimation model is constructed to accurately estimate the concrete compressive strength. The final test results show that this new algorithm has high estimation accuracy and can be suitable for detecting and estimating concrete compression test data, greatly reducing errors. [7]

4. Application of AI in nanomaterials

4.1. Common AI technologies in nanomaterials application

The impact of machine learning on the progress of nanotoxicology has been given some feedback for comprehensive analysis and prediction of nanomaterial properties. Machine learning for hazard prediction and safety outcomes in nanomaterials technologies are applied, and some remaining unresolved limitations are highlighted. Professionals discovering the use of machine learning or statistical modeling to predict different properties of nanomaterials are shown as examples.

To address the problem that machine learning models are severely limited by toxicity data, the researchers categorized the ecotoxicity of nanomaterials. They used four types of tree algorithms to generate species models capable of predicting material properties. These types of functional trees analyzed most of the samples and data sets very correctly. Moreover, the functional trees also predicted the toxicity of metal nanomaterials to specific substances with almost 100% accuracy for both the training and test sets. This is a very good result for experimental measurements of properties of nanomaterials predicted by machine learning models. Comprehensive combination of material evaluation and computational analysis is the main goal of nanomaterials design. [8]

4.2. Unsolved problems impeding the progress of ML in nanomaterials

If machine learning can reliably predict the properties of new materials, since machine learning is very dependent on the quantity and quality of their training models, the data set for training models would need to be enlarged and diversified. At present, the synthesis of nanomaterials still has a small dataset for training models, which may be solved by increasing the application of toxicological data. However, in the research of nanomaterials, machine learning is generally limited in the diversity of small training on the dataset. Limited by the size of the dataset, information on the molecular and structural characteristics of the nanomaterials was not included, which did not lead to a robust and functional predictive model. Therefore, the properties of nanomaterials are not well predicted by machine learning. At present, nano researchers are trying to use cross-machine learning methods to solve the problem of the difference in data gaps.

5. Discussion

A simple analysis of the application of concrete and nanomaterials through machine learning directly proves that whether it is common materials or relatively rare high-tech molecular atomic materials, AI has a great impact on them. Its potential in the future is also huge. However, for nanomaterials, the number and diversity of new models are still relatively limited. Although the development potential is unlimited, researchers may need more time to try to study and analyze some areas that we have not designed so far. The uncertainty brought about is also very worthy of attention. For concrete materials, their development prospects and practicability are obviously better than nanomaterials. The main reason is that as a universal material with a long history, there are countless types after long-term research. People have a clearer all-round positioning and understanding of it. Researchers can combine different specific types, combining their strengths and weaknesses. Coupled with the assistance of more accurate algorithms through AI, it is only a matter of time before we get more accurate innovative products.

As the most promising arithmetic method in AI, machine learning still has great potential in the safe development and use of various materials. Based on the analysis of this work, the obstacles in this field are mainly due to the scarcity of data for training models. If this limitation is to be broken, more detailed and complex and advanced descriptors are needed to encode the properties of substances. In the future, the main task is to try to figure out how to get rid of these obstacles and make machine learning algorithms more practical and rapid development on the basis of ensuring safety.

6. Conclusion

The development of AI is rapid and dazzling in any field. It still has huge development prospects. In this work, concrete and nanotechnology are discussed in detail as representatives of common and rare materials that are affected by AI algorithms in the field of construction. The article also further confirms the development and resistance to the practical application of AI.

In particular, the emergence of machine learning algorithms has pushed AI algorithms to a peak. In terms of concrete technology, although the requirements for concrete performance continue to increase, with the use of various new algorithms in machine learning, such as ANN algorithms and continuous learning algorithms, the model can understand the concept of the problem and estimate the concrete strength with high accuracy. Complete various attribute detection. AI algorithms help greatly reduce errors in practical application analysis of concrete, allowing concrete materials to be put into practical applications more precisely. Through the attention and development of various regions in these years, the potential of AI algorithms for concrete technology is still immeasurable.

Based on the analysis of this work, the obstacles in this field are mainly due to the scarcity of data for training models. If this limitation is to be broken, more detailed and complex and advanced descriptors are needed to encode the properties of substances. In the future, the main task is to try to figure out how to get rid of these obstacles and make machine learning algorithms more practical and rapid development on the basis of ensuring safety.

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