Theory and Practice of Science and Technology
2024, VOL. 5, NO. 6, 136-140
DOI: 10.47297/taposatWSP2633-456920.20240506

Application of Optimization Algorithm Based on Artificial Intelligence in Green Building Design

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ABSTRACT

The design performance optimization of green building schemes requires consideration of factors such as energy consumption, carbon dioxide emissions, thermal comfort, construction cost, and others, and a comprehensive weighing of high-dimensional performance objectives. As the number of performance optimization objectives increases, the design optimization of building schemes becomes increasingly difficult. The existing optimization methods have difficulties in addressing issues like the low efficiency of performance prediction and the complex decision-making in green building optimization design. This paper proposes the application of the optimization algorithm based on artificial intelligence to the field of green building design, and combines computer simulation technology and artificial intelligence deep learning to enhance the efficiency of green building design performance prediction. Employing the particle swarm optimization algorithm and various traditional optimization algorithms to search for the optimal solution of the green building design scheme, in combination with the TOPSIS performance comprehensive evaluation method, can effectively improve the scientific design decision.

KEYWORDS

artificial intelligence; Optimization algorithm; Green building; Architectural design

1 Introduction

In the context of global warming, China proposed at the 75th session of the UN General Assembly that it would reach the peak of carbon dioxide emissions around 2030 and strive for the major goal of carbon neutrality by 2060. According to the statistics of the International Energy Agency, globally, approximately 36% of the total energy consumption and 40% of the carbon dioxide emissions are emitted by the building sector. Thus, reducing the energy consumption and carbon emissions of buildings plays a highly significant role in energy conservation and the mitigation of global warming. China's construction industry has considerable potential for energy conservation and carbon emission reduction. According to statistics, the proportion of non-high-energy-consuming buildings in China is less than 1%. Even in ongoing construction projects, 85% of the buildings are still energy-intensive. Therefore, the construction of green buildings, the reduction of building energy consumption, and the lowering of carbon dioxide emissions will be an important approach for China to successfully achieve the 2030 carbon dioxide emission reduction target. [1]

Throughout the entire life cycle of a building, the design of the building scheme plays a decisive role in achieving energy conservation and emission reduction. To ensure that the building possesses

excellent energy-saving and emission reduction performance, it is necessary to continuously optimize the building design scheme. The traditional method for optimizing the architectural design scheme is mainly accomplished through the subjective experience judgment of architectural designers or the simulation analysis of architectural performance, which makes it difficult to analyze the pros and cons of all architectural design schemes. Architectural scheme design is a multi-factor balancing process; besides considering energy consumption and carbon dioxide emissions, it is also necessary to take into account aspects such as indoor temperature comfort and building costs. In recent years, multi-objective optimization design theories and methods based on parametric performance simulation have emerged in the field of green building scheme design. Various optimization algorithms can automatically assess the advantages and disadvantages of various design schemes and select the optimal one. However, as the number of performance optimization objectives increases, optimizing the design of building schemes becomes increasingly challenging. The existing optimization methods struggle to address issues such as the low efficiency in predicting the performance of optimized designs of green buildings and the complex design decisions of building schemes, making it difficult to select the building design scheme with the best energy-saving and emission reduction performance. Therefore, under the guidance of multi-objective optimization of green buildings, it is of great significance to study the application of artificial intelligence algorithms to assist in green building scheme design. [2]

2 Development status of artificial intelligence

2.1 The first stage of AI development (shallow learning)

In the late 1980s, the invention of BP algorithm became a milestone in the history of artificial neural network development, and set off a boom in the study of artificial intelligence. Artificial neural network models can learn various statistical rules from massive training samples by using BP algorithm, and make predictions about future events. Although the artificial neural network at this stage is called multi-layer perceptron, it faces many difficulties in the training of multi-layer neural network, and the actual model used is a shallow model containing only single-layer hidden nodes. In the 1990s, scholars successively proposed various shallow models of machine learning, which achieved great success in theoretical analysis and practical application. With the rapid development of the Internet after 2000, there is a great demand for intelligent analysis and prediction of all kinds of big data. The shallow learning model of artificial intelligence has achieved great success in the application of the Internet, including the ranking of web search content and the prediction of advertising click rate. [3]

2.2 The second stage of Artificial Intelligence Development (Deep learning)

In 2006, Professor Hinton, an authority in the field of artificial intelligence machine learning, published a paper in the academic journal Science, which opened the upsurge of artificial intelligence deep learning applied to the industry. Since then, deep learning has been heating up in the industry, and since 2011, researchers at Microsoft and Google have successively used DNN technology to reduce the error rate of speech recognition by 20-30%, making breakthrough progress in the field of speech recognition in recent decades. In 2012, the use of DNN technology in the field of image recognition made an amazing breakthrough, reducing the error rate of image recognition from more than 25% to 15%. In 2012, DNN technology was also applied to the drug activity prediction problem of pharmaceutical companies, and achieved very good results. The 2024 Nobel Prize in Chemistry has been awarded to three scientists who have made outstanding

contributions to the design and prediction of protein structures. Two of the winners are from Google's AI company, Demis Hassabis, CEO of Google DeepMind. And DeepMind scientists John Jumper, Demis Hassabis and John Jumper collaborated to develop an AI model to solve the prediction problem of complex structure of proteins that had not been solved for more than 50 years. AlphaFold3 successfully predicted all molecules of life with unprecedented accuracy, and the AlphaFold3 model was around 50% more accurate in tests than the best existing traditional methods, and deep learning was back in the spotlight. In the era of big data, more powerful deep learning models can deeply reveal the information carried by large amounts of data and make more accurate predictions for unknown events. [4]

3 Application of optimization algorithm based on artificial intelligence in the field of green building design

The design performance optimization of green building schemes needs to consider energy consumption, carbon dioxide emissions, thermal comfort, construction cost and other factors, and needs to comprehensively weigh high-dimensional performance objectives. At present, there are problems in the field of green building design, such as low efficiency of performance prediction and optimization and very complicated design decisions. By using BIM modeling and simulation, artificial intelligence design based on deep learning, particle swarm optimization algorithm and traditional algorithm to search for the optimal solution, topsis performance comprehensive evaluation method, the optimal design scheme of green building design can be obtained.

3.1 BIM simulation

BIM simulation refers to the establishment of BIM models to simulate and predict various physical phenomena (including thermal, acoustic, optical, mechanical, etc.) and behaviors of the objective world. BIM simulation is an important integration of computer science, mathematics and engineering science, which can deepen the understanding and knowledge of various physical phenomena in the objective world, conduct computer modeling and calculation of buildings and their environment, simulate and predict complex construction behavior and building environment, and predict the optimization of building design performance. The cost of conducting real experiments in the field of construction engineering is very high, especially some destructive experiments, such as building fire performance experiments or building structural mechanics experiments. Therefore, simulation-based design is a key approach to green building design, and the most critical issue is to establish computational models and algorithms that can accurately and efficiently simulate the behavior of buildings under thermal, acoustic, optical and mechanical conditions. [5]

3.2 Intelligent design based on deep learning

Since 2012, deep learning technology has grown rapidly, and intelligent algorithms with multi-scale, multi-dimensional and big data feature extraction and learning capabilities have great application potential in the field of green building design. At present, with the gradual development of architectural design technology, an inherent working mode has been formed for conventional architectural design. However, it is still difficult to meet the requirements of architectural design even though it relies too much on manual labor and the labor intensity of architectural designers is relatively high, and it is difficult to make effective use of a large number of architectural design materials accumulated in the architectural design industry, making it difficult to inherit architectural

design experience. Conventional architectural design is faced with the problems of low design efficiency and difficult to learn design data. Artificial intelligence deep learning method can master the potential building design laws by learning the existing building design data, and has great application potential in the field of green building design. The intelligent algorithm that effectively learns the design characteristics of green buildings and deduces the design can improve the efficiency of performance optimization and prediction.[6]

3.3 Multiple optimization algorithms jointly search for the optimal solution

Conventional optimization algorithms such as PESA2, SPEA2 and NSGA II have many advantages, but their disadvantages are also obvious. The advantages of NSGA□ optimization algorithm are relatively high efficiency, good distribution of its solution set, and very good performance for low-dimensional problems. Its disadvantage is that it has process defects for high-dimensional problem solution sets, and the diversity of solution sets is not ideal. The advantage of PESA2 optimization algorithm is that its solution convergence is very good, and it is easy to approach the optimal solution, especially in the case of high dimensions. The disadvantage is that the time consumption is very large. The advantage of SPEA2 optimization algorithm is that it can obtain a solution set with a very good distribution, especially for solving high-dimensional problems, but its clustering process takes a long time and its operating efficiency is low. Particle swarm optimization algorithm has the global optimization ability. By remembering the optimal solution and continuously trying to find a better solution, particle swarm optimization algorithm can avoid the dilemma of local optimal solution. Moreover, the swarm intelligence characteristics of particle swarm optimization algorithm enable the optimization algorithm to have the ability of rapid convergence and have a strong advantage in dealing with nonlinear high-dimensional optimization problems. Moreover, the algorithm is easy to combine with traditional optimization methods, and several algorithms such as particle swarm optimization algorithm, NSGA□ and SPEA2 are involved in the optimization process respectively, which can improve the limitations of a single optimization algorithm and solve the problem more efficiently.

3.4 Topsis performance comprehensive evaluation method

Using topsis mathematical modeling method, the green building design scheme was evaluated in multiple dimensions. The evaluation index system is constructed, and then data is collected, each index of green building is standardized and the weight is determined. topsis method is used to calculate the distance between each scheme and the optimal solution, and the sorting result and comprehensive score are obtained.

3.5 Technical Routes

(1) Establish BIM models to accurately simulate and predict thermal, optical, mechanical, acoustic and other phenomena and behaviors of buildings, and construct intelligent algorithms based on artificial intelligence deep learning to effectively learn green building design features, so as to improve the efficiency of optimization and prediction of green building design performance.

(2) Particle swarm optimization algorithm and a variety of traditional optimization algorithms are used to jointly search for the optimal solution of green building design schemes, and a design decision module based on TOPSIS performance comprehensive evaluation method is constructed to improve the scientific nature of green building design decisions, and a multi-objective design optimization process for green buildings is established.

4 Conclusion

Aiming at the problems such as low efficiency of performance prediction and optimization in the field of green building design and complex decision making, this paper puts forward the application of optimization algorithm based on artificial intelligence to the field of green building design.

(1) The design performance optimization of green building schemes needs to consider energy consumption, carbon dioxide emissions, thermal comfort, construction cost and other factors, and needs to comprehensively weigh high-dimensional performance objectives. With the increasing number of performance optimization objectives, the design optimization of building schemes is becoming more and more difficult. The existing optimization methods are difficult to solve the problems such as low efficiency of performance prediction and complex decision making of green building optimization design.

(2) The combinatio of computer simulation technology and artificial intelligence deep learning for green building design can improve the efficiency of green building design performance prediction.

(3) Using particle swarm optimization algorithm and a variety of traditional optimization algorithms to jointly search for the optimal solution of green building design scheme, combined with topsis performance comprehensive evaluation method, can effectively improve the scientific design decision.

(4) This paper proposes a method to apply the optimization algorithm based on artificial intelligence to the field of green building design. However, it is also necessary to combine the optimization algorithm based on artificial intelligence and BIM-related software to conduct secondary development of BIM software according to the characteristics of different engineering projects, so as to get better application in the green building design of specific engineering projects.

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