Research on Energy-efficiency Building Design Based on BIM and Artificial Intelligence

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Abstract: The development of architectural design is closely related to computer technology. With the growth of my country's economy and the rapid development of computer technology in urbanization, artificial intelligence technology has provided new research methods for the construction industry. At present, my country's construction industry is booming, and building energy consumption is also increasing rapidly. To guide the construction industry to develop energy-efficiency and green, various construction companies actively develop building energy-efficiency technologies. As an emerging technology in the construction industry, BIM technology has had an important impact on parameter setting, cost control, professional collaboration and information management in construction engineering. Based on the development of BIM technology and artificial intelligence technology, this paper explores the specific application of BIM and artificial intelligence technology in energy-efficiency buildings, proposes an energy-efficiency building design framework based on BIM and artificial intelligence technology, and analyses the use of BIM and artificial intelligence in the design of energy-efficiency buildings. The value of innovative technology provides a reference for relevant personnel in the industry.

1. Introduction

After Google's AlphaGo artificial intelligence program (AlphaGo) defeated the top human Go players, and its research team published the latest artificial intelligence algorithm in "Nature" magazine, artificial intelligence has now become the outlet for the development of all walks of life direction. The construction industry, a representative of traditional industries, is also working hard to integrate into this tide. Artificial intelligence has gradually shown its advantages in intelligent building design, green energy saving, and operation and maintenance management. With the development of my country's social economy and the acceleration of urbanization, buildings pose a more significant challenge to energy consumption. The energy-efficiency design technology in construction engineering has undergone tremendous changes with the innovation of computer information technology. BIM technology is another revolutionary technology after CAD technology. It represents a concept of perfecting model information and realizing full-cycle information sharing of models. It is a higher level for the traditional CAD model of information exchange model: information integration and standardized interaction concepts. Therefore, making full use of artificial intelligence and BIM technology has essential scientific significance in designing energy-efficiency buildings.
2. Application of BIM technology in energy-efficiency building design

In recent years, our country's building energy consumption has increased year by year, and its proportion is close to a quarter of the total building energy consumption. For the needs of social and economic development and to alleviate energy demand and reduce air pollution, the construction of energy-efficiency and low-carbon buildings in the direction of future growth.

2.1. Elements to be considered in building energy-efficiency design

(1) Natural factors. Factors such as solar energy, environment, wind energy, and climate all affect building energy conservation, making full use of natural resources, rational use of space resources, adapting to the local environment, making full use of renewable energy, and scientifically carrying out architectural design regional characteristics.

(2) Social factors. With the development of new technologies such as big data, cloud computing, the Internet of Things, and artificial intelligence and the improvement of construction-related equipment, people have higher and higher requirements for various intelligent experiences in buildings. If colleagues are meeting people's growing needs, considering the energy-efficiency design of buildings is a problem.

(3) Humanistic factors. The realization of energy-efficiency buildings is inseparable from people's consumption patterns and lifestyles and is also influenced by local folk culture. Therefore, through the implementation of energy-efficiency design work, not only can rationally and scientifically improve the environment and help maintain people's physical and mental health.

2.2. BIM technology and energy-efficiency buildings

Building Information Management System (BIM) is currently gradually accepted by the market and steadily applied in architectural design. Some major domestic projects have used BIM technology for project construction and management, such as the National Aquatics Center (Water Cube), Shanghai World Expo China Pavilion, Beijing Municipal Service Center, Tianjin International Cruise Terminal, Xuzhou Central Stadium, etc. [1].

In the development of my country's construction industry, environmental protection is becoming more and more evident. The application of building energy-efficiency design optimization measures should be carried out under a scientific and economic framework. The BIM technology platform can realize the construction of building models and can also check the building energy-efficiency design schemes. In the specific design, not only must actively use diversified energy-efficiency strategies but also Long-term maintenance and energy-efficiency renovation to continuously improve the building's energy-efficiency effect and provide protection for the long-term environmental protection value of the building.

One advantage of applying BIM technology in building energy-efficiency design is that it can form various data and information association systems. Using the powerful information integration capabilities of BIM technology, building energy-efficiency designers can integrate information in the design, construction and even operation of building energy-efficiency technology applications. Analyses and predict the energy consumption and maintenance costs during the use of the building, providing a guarantee for the overall optimization of the building's energy-efficiency design.

The current BIM technology has been widely integrated into the building design and construction management links. The scientific use of BIM information technology can provide suggestions for building design optimization. At the same time, because BIM has the function of energy consumption prediction, the BIM technology platform can provide energy analysis reference for applying energy-efficiency schemes of building models, there by assisting in building energy-efficiency design.

3. Artificial intelligence algorithms in architectural design

The development of engineering construction technology is inseparable from the support of computer technology. As an essential branch of the computer field, artificial intelligence emerged in the 1950s and is a necessary subject with prospects for multi-disciplinary applications. Artificial intelligence
studies the realization methods of machine intelligence and intelligent machines. In the design process of machine intelligence, a large amount of data in the professional knowledge base is used for learning and training. The device simulates the thinking process and laws of human beings. Then an intelligent machine with particular learning ability and judgment, and decision-making ability is obtained.

In the work that can be done by artificial intelligence, there are not many related to actual architectural design. However, it is still possible to apply machine learning and big data processing to it. For example, Mehmood summarized artificial intelligence and big data in building energy-efficiency and comfortable indoor living environment [2]. Taking artificial intelligence supervising algorithms as an example, some scholars have used the advantages of artificial neural networks (ANN), convolutional neural networks (CNN) and other algorithms to try to explore architectural design [3].

3.1. Artificial Neural Network
The idea of Artificial Neural Networks (ANN) is derived from the way the human brain thinks. It is composed of artificial neurons and can be used to simulate the human brain and nervous system. In 1957, Frank Rosenblatt of Cornell University demonstrated the first trainable neural network called a perceptron. In neural networks, weight factors are often used to model the relationship between input and output vectors. During training, the model's error is calculated, and the weights are updated using stochastic gradient descent or other schemes to minimize the error of the model. It models the time dependence of the target data through a feedback connection [4]. Compared with other models, ANN technology is better at modelling multivariate problems. In multivariate problems, complex relationships between variables are shown. ANN technology can extract nonlinear relationships from variables by learning from training data. The most successful application of neural networks is to predict the electrical load of buildings.

3.2. Convolutional Neural Network
Convolutional Neural Network (CNN) is the most commonly used computer neural network algorithm, recognizing design data as 2D pixelated images. As long as the input data can be expressed as a 2D or 3D matrix, it can be used for recognition. Most artificial intelligence technologies for image recognition are based on CNN. In recent years, image recognition technology using convolutional neural networks has achieved great success in various research and industrial fields. The open-source framework supporting image recognition tasks and pre-trained image recognition models allow us to retrain the model to apply it to any area easily. Through the input learning of massive pictures, CNN can summarize relevant picture features and connect with fixed data. For example, after learning, a computer can recognize a house from a bunch of pictures. At the application level in architectural design, CNN uses digital images to identify interior design elements' design features automatically. Scholars train CNN to recognize the idea of architectural furniture and its characteristic parameters, such as furniture material, seating capacity, design style etc. [5].

4. Application of BIM and artificial intelligence technology in energy-efficiency building design
BIM is an essential part of digital architectural design, but it does not actively generate plans. Instead, it uses BIM methods to manually input architectural design plans into the system, which becomes a graphic and data language that computers can understand. A sharable digital information platform around construction projects. BIM will indeed become an essential link between the digital virtual building world and the natural world in the future. With the help of artificial intelligence, we can balance and organically combine people's complex needs for spatial cognition and aesthetics with the ecological energy saving of the physical environment of the space, human comfort control and other indicators. To solve the problem that the energy-efficiency effect of traditional energy-efficiency ecological buildings often contradicts the complex external form and internal space, it creates a structure with rich spatial experience and energy-efficiency ecology.
4.1. Overall architecture design
Energy-efficiency construction design based on artificial intelligence and BIM includes data collection, artificial intelligence platform, and energy-efficiency building design. Figure 1 shows how artificial intelligence and BIM are applied to the design and operation of energy-efficient buildings. The artificial intelligence platform can be composed of computer processors and various artificial intelligence algorithms, computer codes and simulation software. It also includes monitoring for data display, visualization, and software.

![Diagram](image_url)

- **Data collection**: BIM obtains information such as HVAC and lighting systems, roof material insulation data, energy consumption data of moving doors and windows, adjustable glass, energy consumption data of electric doors and windows, energy consumption of water supply and drainage system equipment, etc. Sensors obtain information such as temperature, light, humidity, etc.
- **Artificial intelligence platform**: Computer software and hardware for data mining and analysis, computer simulation software, visualization tools, etc. AI algorithms: Artificial Neural Networks, Convolutional Neural Networks, machine learning, etc.
- **Energy-efficient building design**: Design index design of energy-efficiency building, Energy-efficiency building design data interaction process, Energy-efficiency building design data analysis, Energy-efficiency building design evaluation index

After analysing the data obtained from BIM and related data received from sensors in real-time, the artificial intelligence platform selects one or more artificial intelligence technologies and algorithms to operate each building component to achieve the best-operating conditions. The artificial intelligence platform can also provide relevant parameters, including local and global weather data, building codes and historical data, and databases related to energy research and sustainable buildings developed by society, research groups and commercial companies. To make full use of artificial intelligence, the heating/cooling/lighting system should be very energy-efficient and versatile. The functions and attributes of the main components of the building designed by BIM should be highly adjustable. In addition to using simulation models, machine learning and deep learning algorithms can also improve accuracy. The main advantage of using machine learning is that machine learning learns from the system's behaviour or the observed data. It emphasizes prediction accuracy rather than model accuracy. Deep understanding uses multiple layers of abstraction to model more complex functions [6].

4.2. Energy-efficiency building prediction based on neural network
To optimize the design of energy-efficiency buildings, designers need to accurately assess the energy-efficiency performance of structures under multi-environment coupling and perform performance
ranking and optimization screening of feasible solutions for building design. Therefore, designers need to rely on building energy-efficiency performance prediction technology.

Expanding the intelligent prediction of building energy-efficiency performance needs to consider the coupling effect of multiple environments such as light and heat environment, wind environment, solar radiation, and the influence of numerous behaviours such as window opening, energy use, and field of view changes. The prediction process needs to be integrated and calculated. The building environment and user behaviour data types, and large amounts of data in the building environment have high requirements on algorithms and computing power. At the same time, the calculation results are affected by the input calculations, which have uncertain and nonlinear characteristics and significant constraints. Intelligently optimize design efficiency based on building energy-efficiency performance. In the face of the above problems, the intelligent prediction technology of building energy-efficiency performance needs to integrate building information modelling, parametric programming and artificial neural network prediction modelling technology to improve the accuracy and efficiency of green performance prediction. The intelligent prediction process of building energy-efficiency performance based on neural network is shown in Figure 2.

![Performance prediction process of energy-efficiency buildings based on neural network](image)

The designer first designs a structure for intelligent prediction of building energy-efficiency performance based on the energy-efficiency performance targets to be evaluated and predicted and the types of building optimization design parameters, including determining the number of neural network layers and neurons, selecting the neural network transfer function, and setting the neural network learning algorithm. Then the neural network model training data is generated through field measurement or simulation. Finally, the training and correction of the intelligent prediction model for building energy-efficiency performance are launched. To break through the bottleneck of building energy-efficiency performance prediction accuracy and efficiency, support the smart optimization design process of building energy-efficiency performance.

The use of artificial intelligence in energy-efficiency buildings can establish an artificial intelligence-based monitoring platform for construction equipment. Integrating BIM and artificial intelligence into building design and using the energy consumption prediction function of BIM technology can provide energy analysis reference for applying energy-efficiency schemes in building models. Assist in building energy-efficiency design and provide suggestions for optimizing building design.

5. Conclusion
After decades of development and improvement, artificial intelligence has now taken root in our daily lives. It has begun to have a profound impact on the field of architecture and sustainable development.
Artificial intelligence applications in sustainable buildings include energy-efficient building design, forecasting and minimizing energy consumption, formulating strategies to reduce the impact on the environment and climate, and improving the safety and comfort of the living environment. Regardless of the effects of artificial intelligence on architectural design, big data is the key according to the current artificial intelligence algorithm requirements. Through continuous data accumulation, BIM has formed massive data for digital building design, which can gradually form the significant data foundation for artificial intelligence design. This paper first introduces BIM technology and artificial intelligence algorithms in architectural design. Then it discussed how to use BIM and artificial intelligence to design energy-efficient buildings. Finally, it is emphasized that the combination of artificial intelligence and BIM can significantly improve the energy efficiency and cost-effectiveness of buildings, which are designed to provide residents with a comfortable indoor living environment.

References

[1] LIU Zhan-sheng, ZHAO Ming, XU Rui-long. Research and Application Status of BIM in China (in Chinese) [J]. Architecture Technology, 2013,44(10):893-897.

[2] Mehmood M U, Chun D, Zeeshan Z, et al. A Review of the Applications of Artificial Intelligence and Big Data to Buildings for Energy-Efficiency and a Comfortable Indoor Living Environment[J]. Energy and Buildings, 2019(202):109383.

[3] Zhou Xiang. Application of artificial intelligence algorithm in architectural design (in Chinese) [J]. Chinese & Overseas Architecture, 2019, 221(09):49-52.

[4] Aowabin R, Smith A D. Predicting heating demand and sizing a stratified thermal storage tank using deep learning algorithms[J]. Applied Energy, 2018(228):108-121

[5] Kim J, Lee J K. Approach to the Extraction of Design Features of Interior Design Elements Using Image Recognition Technique. 2018:287-296.

[6] Rahman A, Srikumar V, Smith A D. Predicting electricity consumption for commercial and residential buildings using deep recurrent neural networks[J]. Applied Energy, 2018, 212(FEB.15):372-385.