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Application of BIM in Public Building Energy Management System

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Abstract: *High energy consumption is an important issue in current public buildings. This paper proposes a public building energy management system based on Building Information Modeling (BIM), which applies BIM technology on the basis of existing public building energy management system. This system combines energy consumption information, environmental information, and building property information monitored by IoT devices for energy consumption prediction and analysis to obtain optimization strategies, and controls energy consuming devices to achieve the goal of improving building energy efficiency.*

Keywords: *BIM, Public Buildings, Energy Management*

1. Introduction

According to data of the International Energy Agency, one-third of the total global energy consumption is the energy consumption of the construction industry. With the growth of population and the acceleration of urbanization, the energy consumption of the construction industry is continuously increasing. Among them, the phenomenon of energy waste in the operation of public buildings is relatively serious, and there is a lot of energy-saving space. Building energy management (BEM) is an effective energy-saving management measure during the operation of buildings. In recent years, the Ministry of Housing and Urban-Rural Development of the People's Republic of China and local governments in China have successively issued corresponding policy documents to vigorously promote the construction of public building energy management platforms. However, the current energy management system faces the problem of "information silos", as well as the lack of deep mining of monitored energy consumption data, which makes it difficult to truly achieve energy-saving control. With the development of Building Information Model (BIM) technology, the advantages of BIM technology in 3D visualization, information integration and simulation analysis can solve the existing problems of energy management system to a certain extent. This paper integrates BIM technology into the energy management process of public buildings and constructs a BIM-based energy management system for public buildings, aiming to improve the efficiency of energy management in public buildings.

2. Application of BIM in Building Energy Management

BIM technology has been widely applied in the construction industry. It can integrate various relevant information of construction projects into 3D digital models. It can be applied to all stages of the building lifecycle, such as planning, design, construction, operation, and maintenance periods, with characteristics such as intuitiveness, data integrity, centralization, and scalability. The application of BIM technology can help construction projects achieve collaborative work, improve efficiency, and reduce costs.

In recent years, the integration of BIM and public building energy management has received increasing attention. At present, the researches on BIM in the field of energy management mainly focus on visual monitoring of building energy and energy statistical analysis. For example, in[1], the IoT and BIM are integrated to build a smart operation management platform, which can be used for energy monitoring and real-time feedback. [2] takes Wuhan International Expo Center as the research object and uses BIM technology for energy consumption statistical analysis. Based on this, the basic functions and system architecture of the energy consumption monitoring system are designed. The BIM energy consumption monitoring and analysis system designed by [3] has been successfully applied in a power engineering project in Shanghai, providing scientific basis and effective means for optimizing building

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energy-saving operation management. [4] shows that combining energy analysis tools with BIM models can accelerate the energy analysis process, provide more detailed and accurate results, help predict and optimize energy consumption, and achieve energy-saving effects. Many studies have shown that applying BIM to energy management can effectively improve the energy efficiency of buildings. However, further research is needed on the limitations of data integration, energy consumption analysis, and energy optimization control.

3. BIM-based energy management system for public buildings

This paper proposes a BIM based public building energy management system, as shown in Figure 1. This system adopts a three-layer framework: device layer, transport layer and application layer. The device layer is responsible for collecting various relevant energy consumption data and environmental data, such as power consumption data, water consumption data, indoor temperature, indoor humidity, indoor illumination, etc., and receiving optimization control commands to adjust equipment operation. The transmission layer adopts wireless sensor network (such as zigbee network) to transmit various data collected by the device layer to the application layer, and transmit the control instructions of the application layer to the device layer, playing a role of linking up the upper and lower layers. The application layer includes BIM modeling, energy consumption optimization, energy consumption display, and query modules.

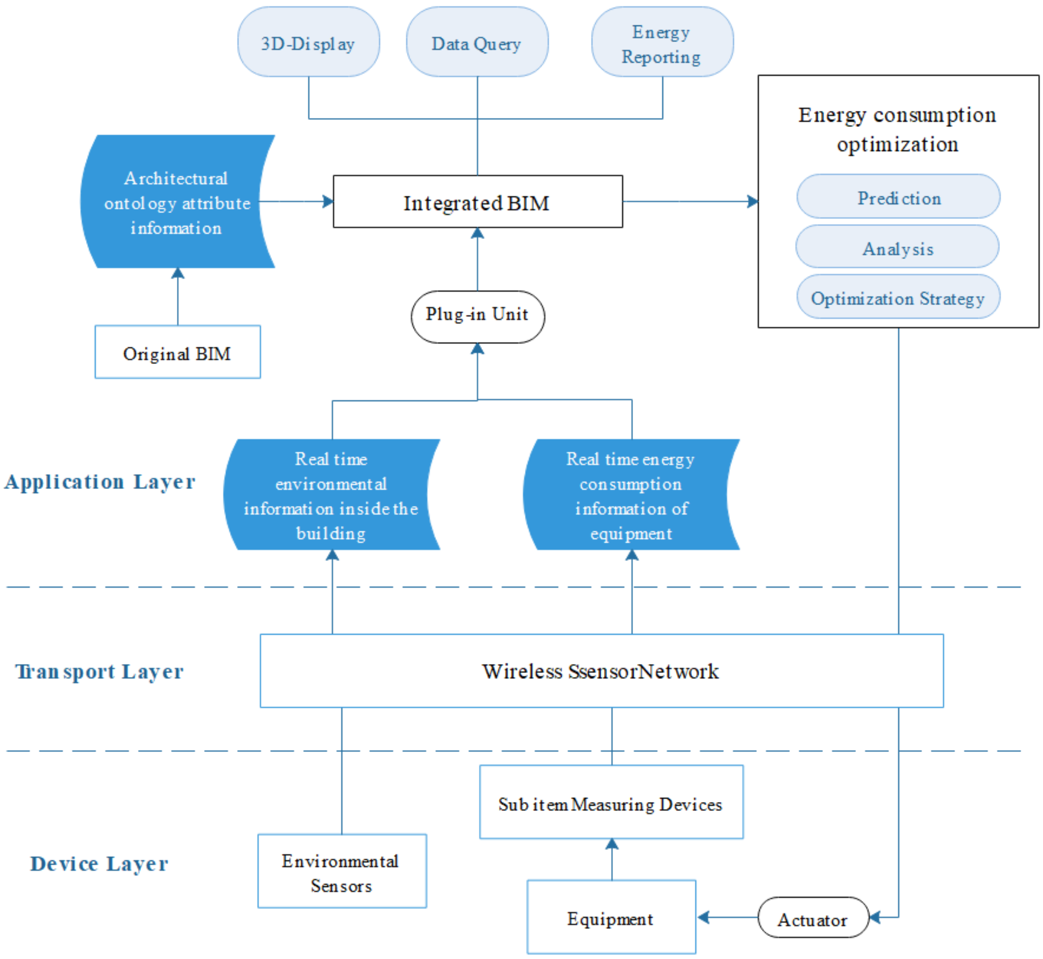

Figure 1: The Framework of Public Building Energy Management System Based on BIM

Specifically, the system proposed in this paper has the following functions:

(1) Data collection and processing. This system can monitor building equipment in real-time and process data to obtain equipment operation status and energy consumption information.

(2) Energy consumption analysis and evaluation. This system can simulate and analyze building energy consumption using BIM technology based on collected data, evaluate the energy consumption of

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buildings, and provide corresponding energy consumption analysis reports.

(3) Energy consumption optimization. This system can propose corresponding optimization measures for equipment or areas with high energy consumption based on energy consumption analysis results, such as equipment optimization operation strategies, energy consumption control and regulation, etc. In addition, machine learning and other methods can be used to predict the failure of construction equipment, carry out maintenance and repair in advance, and reduce energy consumption and maintenance costs.

(4) Data visualization and management. This system can visualize the collected data and provide data management functions, including data storage, query, management, and export.

(5) Building information integration. This system can integrate the building equipment energy-saving management system with the BIM model, achieve comprehensive management and data sharing of building information, and improve the efficiency of building equipment energy-saving management.

(6) Intelligent control. This system can achieve intelligent control of building equipment based on IoT technology and BIM models, including energy consumption adaptive adjustment, intelligent control, etc., to improve the energy-saving effect of building equipment.

The overall working process of the system is as follows: firstly, the BIM model of the target building is established, which contains the attribute information of the building ontology. Then, the energy consumption and environmental information are monitored through the sub item energy consumption measurement devices and environmental sensors installed in the target building. The above information is integrated into an integrated BIM model, followed by energy consumption analysis and evaluation, optimization strategies are proposed, and finally, equipment operation is controlled to achieve energy conservation.

3.1. Create or optimize BIM models and export building ontology attribute information

If the target building does not have a BIM model, create a BIM model of the building and its internal equipment on Autodesk Revit, with an accuracy of not less than 300LOD, and correctly allocate all required thermal and geometric characteristics of the building envelope structural components to different components in the model. If the target building already has a BIM model in the design phase, it needs to be optimized and improved. The model created in Revit that corresponds to the actual equipment needs to be constructed according to the actual equipment layout and pipeline connection relationship, and the components representing measuring instruments and sensors should be displayed in the BIM model according to their actual positions, as shown in Figure 2.

Then export the architectural ontology attribute information to the integrated BIM model. The architectural ontology attribute information mainly includes: (1) the geometric features of the building, including shape, size, layout, and structural components; (2) The environmental characteristics of buildings, including environmental conditions, spatial distribution, and resource utilization; (3) The functional characteristics of the building, including functional space, equipment and facilities, management processes, and maintenance requirements; (4) The life-cycle characteristics of buildings, including design, construction, operation, and maintenance.

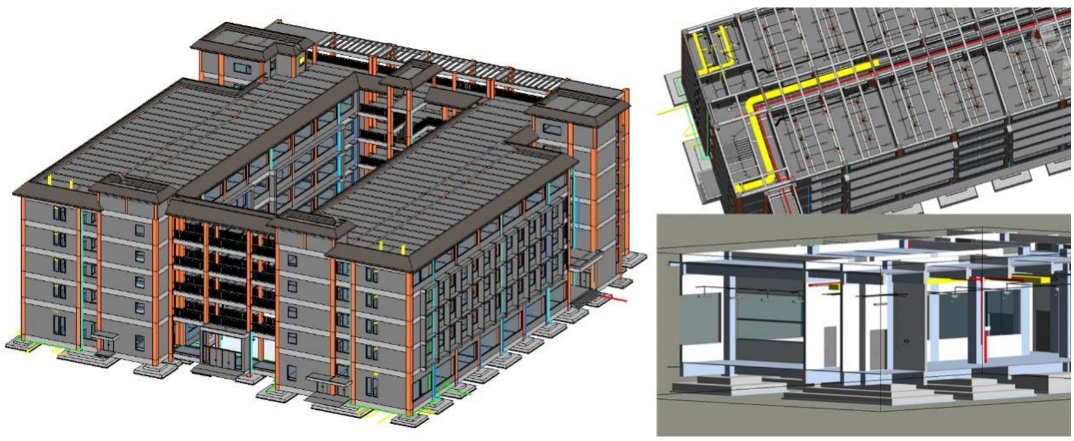

Figure 2: BIM model of the target building (overall and partial views)

3.2. Monitor energy consumption data and environmental data

According to the "Technical guidelines for sub item energy consumption data collection of energy consumption monitoring systems for national office buildings and large public buildings" issued by Ministry of Housing and Urban-Rural Development of the People's Republic of China[5], energy consumption data collection indicators are divided into two types: classified energy consumption and sub item energy consumption. Among them, classified energy consumption includes 6 items, including electricity, water consumption, and gas consumption. Each category of energy consumption is divided into sub items, such as lighting and socket electricity, air conditioning electricity, power electricity, and special electricity. Install sub item metering devices at the source of sub item energy consumption equipment in the target building to obtain specific energy consumption data. In addition, install temperature, humidity, and illumination sensors to collect environmental information such as indoor temperature, humidity, and illumination. The itemized measuring device and environmental sensor should have the function of uploading data in real-time at an hourly frequency.

3.3. Integrate BIM data and sensor data in the system

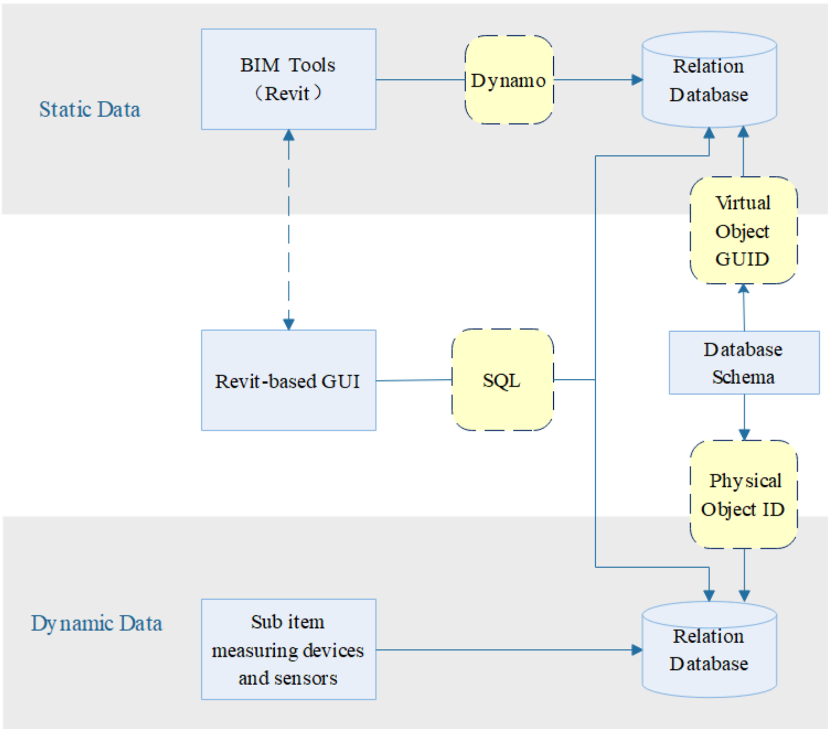

Figure 3: The Integration Method of Dynamic and Static Data

The integrated BIM model database includes two parts of data. The first part is static data, mainly including building ontology attribute information. This data can be stored in the Industrial Foundation Classes (IFC) format file of the BIM model. IFC is a digital modeling format used in the construction industry, which can be used to store and exchange BIM data. IFC format files can enable BIM models to be shared among multiple different software applications, enabling digital building data integration and exchange. The second part is dynamic data, which is time series data collected by itemized measuring devices and sensors. This data can be stored in a structured relational database and queried using Structured Query Language (SQL).

The integration method of dynamic and static data is shown in Figure 3, and the basic steps can be summarized as follows: (1) Store the time series data collected by the sub metering device and sensors in the relational database SQL server and update it; (2) BIM models created in Revit can be exported to a relational database format using the visualization programming tool Dynamo of BIM; (3) Define the database mode, and clarify the relationship between the virtual objects and physical entity of sub item metering devices and sensors. Virtual objects can be associated with physical entity using globally unique identifiers (GUIDs); (4) Implement bidirectional import and export of relational databases and BIM models through application programming interfaces (APIs); (5) Access dynamic data through a Revit

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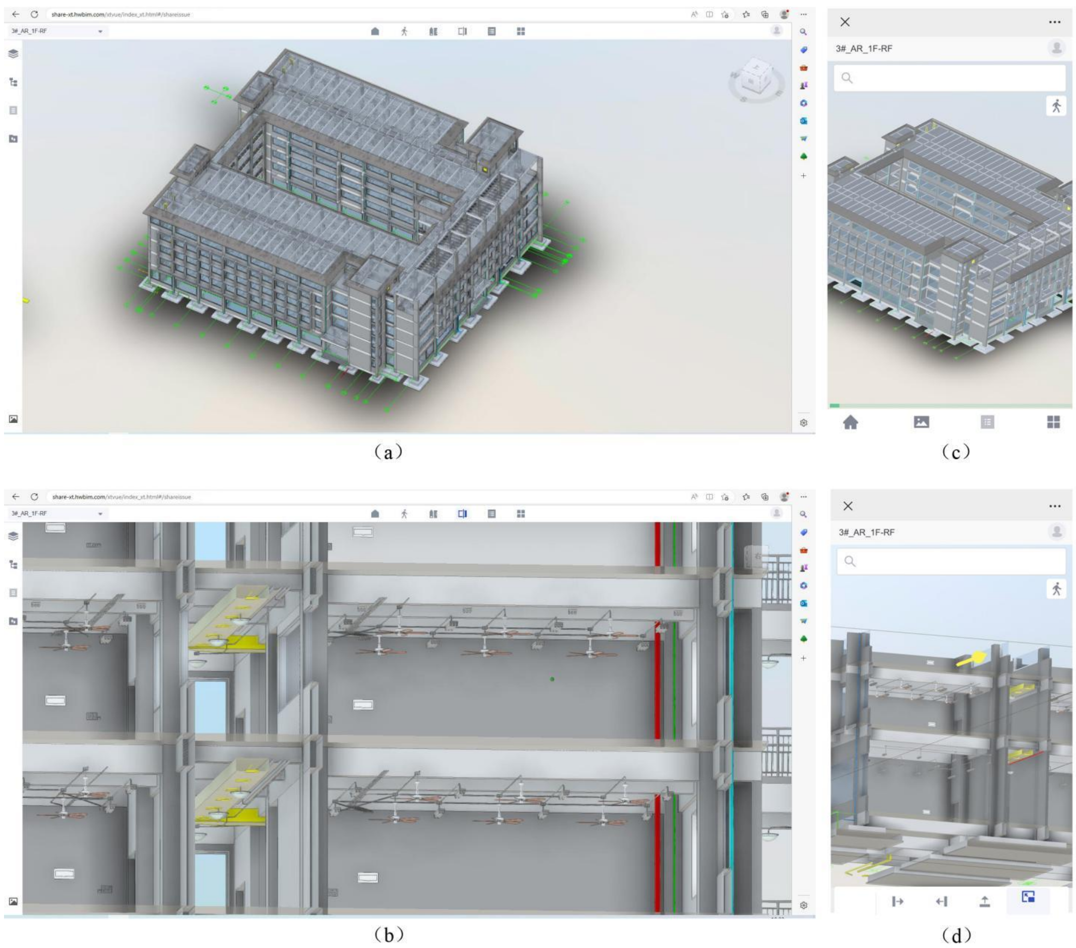
based graphical user interface (GUI) and direct querying of SQL databases. The integration of BIM data and sensor data using this method is relatively simple and feasible, and customized APIs can enable automatic updates of sensor data in BIM tools.

3.4. Optimize energy consumption

The energy consumption of the target building can be predicted using neural network algorithms. Firstly, perform data preprocessing to convert the raw data into a data format that can be recognized by the neural network. Based on the preprocessed data, construct a neural network model that can predict building energy consumption. The input layer sets multiple nodes based on the ontology attribute information, energy consumption data, and environmental data of the target building. The number of hidden layers and nodes depends on the complexity of the data and the accuracy requirements of the prediction. The output layer is the building energy consumption for the future period, which is also the energy demand that the system needs to analyze. Then train the neural network and evaluate the prediction effect, adjust and optimize the model until satisfactory results are obtained. Finally, use the trained model to predict the energy consumption of the target building. Compare and analyze the predicted values with the actual monitoring values to obtain abnormal energy consumption data, provide optimization suggestions for users, and send instructions to the actuator to control the operation of the equipment.

3.5. Lightweight display



(a) Lightweight display on IE browser (overall view); (b) Lightweight display on IE browser (partial view); (c) Lightweight display on mobile APP (overall view); (d) Lightweight display on mobile APP (partial view).

Figure 4: Lightweight display of BIM models for target buildings

Due to the BIM model file containing a large amount of details and complex geometric shapes, the file volume is too large. Lightweight technology can reduce the size of model files by removing redundant data, compressing data, optimizing graphics, and adjusting file structure, thereby helping to improve the efficiency and availability of model files and improve user experience. There are two main platforms for BIM lightweight display: One is a cloud based platform that can be displayed in a browser, as shown in Figure 4 (a) and (b); Another is based on mobile platforms, which can be displayed on apps on mobile devices such as tablets or smartphones. , as shown in Figure 4 (c) and (d). Both platforms do not require users to have a high level of software technology, resulting in strong operability. Integrating the integrated BIM model into a BIM lightweight display platform that can be used for secondary development (such as Guanglianda BIMFACE) can intuitively display the current device operation status, energy consumption data, and environmental data in the 3D model dynamically. In addition, energy consumption trend charts for future periods, energy consumption data charts for historical periods, and energy reports can be generated through a user-friendly interface.

4. Conclusion

This paper proposes a BIM based framework for public building energy management system, and explains the working process and key technologies involved in the system. Applying BIM to energy management in public buildings has the following advantages:

(1) The energy-saving effect has been improved. Applying BIM to energy management systems can comprehensively and systematically manage and optimize the scheduling of building equipment, thereby improving energy efficiency, reducing energy consumption and operating costs. BIM enables device simulation and predictive analysis, and can adjust control strategies based on device operation status and energy consumption to achieve optimal energy efficiency.

(2) The level of intelligence has been enhanced. Applying BIM to energy management systems can achieve intelligent monitoring and control of building equipment, and achieve automatic adjustment and optimization of equipment through functions such as sensing equipment operation status, predicting energy consumption, and anomaly detection. At the same time, device information, energy consumption data, and management indicators can also be transmitted in real-time to the cloud platform, achieving comprehensive remote monitoring and data analysis of devices, thereby achieving intelligent device operation management.

(3) Management efficiency has been enhanced. By using BIM technology to achieve three-dimensional modeling and simulation of equipment, the operational status and energy consumption data of the equipment can be quickly and accurately obtained, achieving comprehensive monitoring and management of the equipment. At the same time, the application of IoT technology can achieve real-time collection and transmission of device information and energy consumption data, achieving comprehensive data-driven device management and optimized scheduling.

(4) Industrial upgrading has been promoted. By utilizing BIM technology to achieve comprehensive digital management and optimized scheduling of equipment, the level and technological content of equipment management can be improved, providing technical support and innovative impetus for the development of the industry. At the same time, the application of IoT technology can realize the real-time transmission and sharing of equipment information and energy consumption data, providing support and guarantee for the Digital transformation and information upgrading of the industry.

At present, the application of BIM in public building energy management is still in the exploration and development stage, and there are some challenges and problems. For example, in the selection, deployment, and maintenance of sensors and controllers, it is necessary to fully consider the type and characteristics of equipment, as well as the reliability and security of data collection and transmission. At the same time, data analysis and optimization control based on the Internet of Things also need to fully utilize technologies such as big data and artificial intelligence to improve the accuracy and efficiency of data processing and decision-making.

In the future, with the continuous development and application of new technologies, BIM based energy management technology for public buildings will be further improved and promoted. This technology can also be combined with technologies such as intelligent buildings and renewable energy to form more comprehensive and comprehensive building energy management solutions, making greater contributions to achieving green buildings and sustainable development.

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