Development and Application of BIM-based Foundation Pit Construction Simulation System

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Abstract. Due to the increasing use of underground space in China, the number of foundation pit engineering is increasing. The emergence of BIM Technology has brought positive impact on foundation pit construction. This paper studies the foundation pit construction simulation system by using BIM technology. After the information processing of the Revit foundation pit model, the JSON format model is exported. With the JSON model as the core, the web-based foundation pit construction simulation system is built to realize the visual construction simulation of the foundation pit engineering. It is verified by the practice of the World Expo foundation pit project, which provides convenience for the project management and ensures the construction safety. It can be used for reference for the application of BIM in foundation pit engineering.

Keywords: Foundation Pit Engineering, BIM, Construction Simulation, System Development.

1. Introduction
In recent years, with the development of residential construction and subway in China, the excavation and utilization of underground space is increasing, and many foundation pit projects appear. The whole life cycle of foundation pit engineering project is multi-stage, and the personnel involved in the whole project process is a large number of interdisciplinary fields. The inefficiency of information transmission and sharing between them is a major factor restricting the project progress and consuming the project. These difficulties perplex the construction industry personnel for a long time, and the emergence of BIM technology provides a good solution for these problems. Building information modeling (BIM) can simulate the real information of a building by computer simulation technology. Through BIM technology, the gap between the design, monitoring and construction of foundation pit engineering can be broken down, and the difficulty of sharing cooperation and information exchange in different stages can be reduced. All participants of the project can cooperate together. The construction, cost, progress and quality management of foundation pit engineering can be planned and optimized in advance through three-dimensional visual simulation, so as to reduce costs, reduce rework, improve work efficiency.

Domestic and foreign scholars have launched a variety of attempts for the application of BIM technology in the field of foundation pit engineering. Riyadh El-Solh gives the optimization scheme for
the key part of the foundation pit construction process, and realizes the fine management of the foundation pit construction by using BIM technology [1]. Tan Pei, Chen Lizhao, Zhou Longxiang take a deep foundation pit as an example, and use the visualization characteristics of BIM technology to introduce the establishment of 3D model of deep foundation pit, real-time inspection of foundation pit detection data, reinforcement of complex nodes, construction progress simulation and other contents [2]. Based on the Revit software platform, Xiao Bei has carried out secondary development on the terrain, floor, bearing platform, foundation beam and so on in the complex foundation pit excavation, and provided the open source module for development calculation [3].

To sum up, researchers in geotechnical field have carried out a series of exploration and research on the application of BIM technology in foundation pit engineering, whether in the design, construction and even later maintenance of foundation pit engineering. However, the current research is basically based on the software platform side of the foundation pit engineering BIM application research, and different BIM software has different functions, for the application of foundation pit engineering often need more than one software research, it is very inconvenient. The BIM in theory should be able to run through the whole life cycle of construction projects and support the storage and interaction of all project information [4]. Therefore, a platform based on practical technology is needed to realize these characteristics of BIM, and BIM platform emerges as the times require.

In this paper, the BIM-based foundation pit construction simulation system is established to process the information contained in the foundation pit model. The BIM system platform based on B/S architecture is developed. The processed Revit model is imported into the platform and reconstructed and rendered on the web. Combined with this model, the visual simulation of construction is carried out to view the data information of the foundation pit model, and the geological information around the foundation pit is monitored to ensure the quality and safety of the construction process.

2. Design and architecture of BIM foundation pit construction simulation system
Considering the system update, maintenance and development and user needs, the B/S architecture is selected. The system is composed of data layer, business logic layer and presentation layer. The specific system architecture is shown in Fig.1.

![Figure 1. System framework](image-url)
The data layer mainly includes all kinds of BIM model transformation files, engineering data files, construction schedule and other business-related data. At the same time, the data access interface and database drive are used to respond to the interactive requests from the business logic layer to realize the data information access operation. The business logic layer is between the data layer and the presentation layer, which mainly provides various data and functional business interfaces, and is the logical carrier to realize the business functions of the whole system. The presentation layer is located at the top layer of the system architecture, which directly contacts with users to realize the input and output of data. It is mainly used to receive the user's request and data return, provide the client with access to the system platform, load the foundation pit model, and simulate the construction progress.

The system is based on easyUI framework, Three.js graphics engine and ASP.Net MVC architecture provides interactive operation interface for users.

3. Engineering Application

3.1. Project Overview

The project of Shanghai World Expo is located in the east of Expo Avenue and the west of Xueye Road in Pudong New Area. The geographical location is shown in Fig.2.

![Foundation pit location map](image)

Figure 2. Foundation pit location map

The project is a reconstruction and expansion project. The original building is the Expo East Lake Apartment Hotel, which was completed in 2009. The original building consists of 17 8-20f high-rise hotel style apartments, 14f reserved building (now is Baolaina Restaurant), several 2F ancillary facilities and three underground parking lots (connected by connecting passages in the middle). The planned land area of the project is about 83674.2m², and the total construction area after reconstruction and expansion is about 286752.75m², including 173728.52m² above ground and 113024.23m² underground. In this project, the application of BIM technology to establish a set of foundation pit construction simulation system, to achieve efficient and safe engineering management is of great significance.
3.2. Derivation of Foundation Pit Model

Through the secondary development of the Revit software, the original foundation pit model is exported to JSON format. JSON is a lightweight data exchange format, and its key value pair data storage mode is easy to write and analyze. As a data format loaded on the web side of BIM foundation pit model, JSON has great advantages [5]. The model serialization can be converted into JSON format by using IExportContext interface in the Revit API provided by Autodesk company. Using IExternalApplication interface to write the menu bar of plug-ins can greatly improve the convenience and efficiency of startup. The RVT format foundation pit model is converted into JSON format by plug-in and imported into the system platform.

3.3. Loading of Foundation Pit Model

Three.js is a 3D engine based on native webgl encapsulation, which directly encapsulates various JavaScript APIs about webgl features. Three.js There are three essential components: camera, scene, and renderer. Their relationship is shown in Fig.3. The role of the camera is to determine which objects on the screen need to be rendered. Scene objects are containers for all different objects, including not only all objects, light sources, and other objects needed for rendering. The role of the renderer is to render the scene objects in the scope of the camera in the browser.

![Figure 3. Three.js diagram](image)

Use Three.js to load and export the JSON foundation pit model. Through specific algorithm, the component attribute information in the JSON model is associated with the geometric data to realize the web-side display of the building information model, as shown in Fig.4. The track controller can realize the rotation, scaling and translation of the foundation pit model. With the help of clipping planes, the model cutting function is developed. The ray algorithm is used to select components and display component information.

![Figure 4. Model web display](image)
3.4. Foundation Pit Construction Simulation

The construction process of foundation pit engineering involves various random factors, such as mechanical configuration, natural conditions, operation mode and so on. Therefore, visual simulation technology is generally used for research [6]. However, the visualization simulation research of foundation pit construction progress is carried out by professional simulation software at present, which requires too much computer configuration. The time cost and resource cost of building visualization scene are very high. The application of construction simulation in web platform, through BIM model to analyze the simulation process, reasonably adjust the construction progress, more accurately control the construction and production on site, ensure the construction quality and safety, can greatly reduce the demand for computer software and hardware, and facilitate the staff to view the construction process anytime and anywhere.

In this paper, the group parameter is used to operate the imported components of the foundation pit model, and its visible property is used to operate the components of the model. The data of construction progress mainly includes task name, start time, end time, task type, etc. Through the integration of data schedule and visual model, the visualization of construction progress is realized, which reduces the difficulty of management personnel to understand the drawings, facilitates the construction personnel to understand the engineering construction, and ensures the quality and safety of construction. Taking the enclosure of the working shaft of the foundation pit of the World Expo as an example, the construction progress is shown in Fig.5.

4. Conclusion

Based on the World Expo foundation pit project, this paper establishes the B/S architecture foundation pit engineering construction simulation system with the building information model cloud service as the core. The main conclusions are as follows: 1) The lightweight BIM model is realized and visualized based on Web. 2) It realizes the rapid input of construction information, comprehensive view of geological information and design information, and visual simulation of construction progress. It is verified by the practice of the foundation pit engineering of the World Expo that the system basically
meets the needs of the information management of the foundation pit construction, and has reference significance for the application of BIM in the foundation pit engineering. However, in the process of research and development, there are also some shortcomings, which are expected to be overcome in further research: 1) When exporting JSON model file, there may be a situation that the process cannot be exported due to the large number of components, and the relevant algorithm will be optimized in the follow-up research and development. 2) At present, the function of the system is not comprehensive enough to be applied to the whole life cycle of the project. In the follow-up development, the data monitoring, project cost and other functions will be studied.

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