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Construction Project Design Optimization Platform Research Based on BIM

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With the increasing contradiction of economic development and environmental protection, the simple and crude development model of the construction industry in the past has not suited to the extensive development of sustainable social development needs. Today, more and more people are aware that green building is the inevitable trend of future building which is propitious to energy conservation and environmental protection. This paper uses the BIM application technology to explore the design platform of the green building. This architecture consists of two layers, one is composite layer made up by the presentation layer and the business logic layer, the other is database access layer. On this basis, Grey situation decision-making model is used to optimize construction scheme. The results show that we can reduce construction costs by improving construction engineering design quality and efficiency.

1. Introduction

In recent years, with the rapid development of urban construction, the increasing construction project scale and more complex form in our country, the requirement for construction engineering design is becoming higher and higher (Azhar et al., 2009; Woo and Wilsmann, 2010). However, due to the non-integrated disciplines, the effective and accurate coordination and interaction is scarce during the design process, leading to continuous repeat work, inefficiency production, more construction rework, construction cost rise and severe resources waste in conventional 2D model design (Flager et al., 2009; Azhar et al., 2011; Bynum et al., 2012). It is BIM (Building Information Modelling) that can solve that problem. BIM is another revolution in the field of construction after the two-dimensional CAD technology and the process of engineering project design (Fesanghary et al., 2012). Project can be designed, built and managed by creating and using the digital model. Using BIM technology and computer technology, aiming at some problems of construction engineering design, we put forward the effective solution, which helps to improve information technology and information management level of the design enterprise and enhance the core competitiveness of design enterprise. It must also play a positive role to the development of BIM in China.
In the next section, development platform research of constructional project is investigated. In section 3, Optimization method based on grey theory is used for design optimization. In section 4, pipeline collision (Fabrizio et al., 2010) in the construction process simulation optimization based on BIM is given. Finally, some conclusions are given. Nowadays most construction firms are using information management systems as management tools in construction management and more and more information is being accumulated in the systems with time, relating to such productive elements as labour, machine and material etc., and covering such managerial subjects as schedule, cost, quality, etc. The information that can be reused is called information resources in the context of this study. It could be predicted that by making full use of the information resources, the decision-making in the management could be improved, which thus enhances the competitiveness of construction firms. Traditional methods for utilizing information resources can be grouped into two types, i.e. to extract and analyse information manually and by using such software as BI (Business Intelligence) software. Since the former was not efficient and the latter requires the help of professional consulting, it is difficult for most construction firms to utilize information resources. In order to facilitate utilizing the information resources, a conceptual framework for reusing the information resources was proposed based

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on BIM (Building Information Model) technology, IFC (Industry Foundation Classes) standard and related researches, which extracts information resources project by project and manages them in the standard format. The framework could be divided into four phases, i.e. the extraction, the standardization, the management and the detailed analysis of information resources. In the extraction phase, decision activities and preliminary information resource items were identified by means of literature reviews and expert workshops. The reusability of information resource items was evaluated in an evaluation workshop, and the result was verified in a verification workshop. In the standardization phase, the extension of IFC standard was carried based on the analysis of information resources by using object-oriented method, and information resource items were represented by using the IFC to verify its feasibility. Then the model of information resources based on IFC standard was established to lay its foundation. In the management phase, the performance of managing IFC data in various databases was evaluated and the object-oriented database was selected to store IFC data due to its high performance. Then the method on how to form information resource based on the IFC standard was analysed and the instances were given to verify its feasibility. Based on these analyses, the information resources reuse system named InfoReuse in construction firms was formulated and developed, where object-oriented database and object-oriented programming method were taken. Information resources could be managed and retrieved in the system and such method as multi regression algorithm could be applied to analyse the information. Then the system was applied in the construction firm using real information resource to verity its feasibility and effectiveness of the system. The result of this study has indicated that information resources could be organized and represented by using BIM data standard and the system provides a solution for construction firms, which has important significance for the decision-making of construction firms.

2. Development platform research of constructional project

Construction project design optimization platform based on BIM uses C++ and C# development language, and development platform adopts Visual Studio 2010. Through C++ language, we design algorithm of optimized function modules and encapsulate it into a callable function interface to implement the data storage and conversion. C# language is used to call API functions of modelling platform, which implements data reading of BIM model, the reconstruction of BIM model, and the design of graphical interface.

As to the verify correctness, effectiveness, feasibility of the developed algorithm in this paper, Revit is taken as modelling and testing tool, and call the application development interface provided by Revit platform to create model and test function[7]. This platform adopts C/S structure. C/S architecture adopts two layers of structure, namely composite layer composed of presentation layer and business logic layer, and database access layer. The underlying data are stored by relational database and XML file. The presentation layer is responsible for displaying three-dimensional scene, engineering components and information, which responds to user demand and provides users with interactive user interface based on three dimension display.

Business logic layer is responsible for handling user input information, or send these information to the data access layer to save, or call the data access layer again to read this information, at the same time it realizes adding, deleting, changing and checking operation of data, which provides the business logic support of the entire platform. The database access layer provides data support for the presentation layer and business logic layer. Through the database access layer, the presentation layer and business logic layer can interact with relational database and XML file conveniently. The database access layer mainly accesses SQL Server database through CSQL Helper class and accesses XML file through CXML Helper class. Information model data is divided into two parts. The attribute information is stored by SQL SERVER database, spatial information and geometry information are stored by XML file.

Based on fully considering the BIM technology in the field of construction engineering, the platform can be mainly divided into four modules, data input module, model management module, design optimization module and the user management module. Platform function module partition is shown in figure 1.

Data input module is responsible for inputting all data supporting the normal operation of the whole platform, including model attribute data and spatial information, attribute data of accessory equipment and spatial information, as well as the various data necessary to support the database and so on.

Model management module mainly manages all object model in the platform. In BIM thought, family model is the necessary element constituting the whole construction project and runs through the whole life cycle of buildings, which is the carrier of data undertaking and circulation. Effectively managing the object model can improve the efficiency of the three dimension design, and greatly reduce time and energy because of repeated object model development.

Design optimization module mainly completes specific engineering management for construction project. The main characteristic of BIM is to break through the disadvantages of engineering calculation in two-dimensional design. In BIM platform, however, on the basis of three dimension information model, it can effectively carry out the most engineering calculation by means of digital technology.

The information silo and information gap resulting in the lack of data exchange standards and information integration mechanism during the development of the information of the construction industry, has made it difficult for the exchange and sharing of information during the different phases and different application systems and blocked the application of information technology in the construction area. Therefore, it has become a research direction and trend to build up building lifecycle management framework and develop integrated information management system in order to enhance the application level of IT in building industry. With the increasing contradiction of economic development and environmental protection, the simple and crude development model of the construction industry in the past has not suited to the extensive development of sustainable social development needs. Today, more and more people are aware that green building is the inevitable trend of future building which is propitious to energy conservation and environmental protection. This architecture consists of two layers, one is composite layer made up by the presentation layer and the business logic layer, the other is database access layer. On this basis, Grey situation decision-making model is used to optimize construction scheme. BIM (Building Information Modelling), information standards and information integration technologies are comprehensively applied, and IFC (Industry Foundation Classes) standard is used for improving the performance. A BIM-based building information management system and framework is proposed. BIM architecture, information description, integration and extension mechanism are proposed. And the key technologies of BIM 3D geometric modelling and conversion, partial-BIM information extraction and integration, BIM data storage and access are researched. Based on these, a BIM Information Integration Platform (BIMIIP) is developed, which can read, save, extract, integrate and extend structured IFC model data and unstructured documents, define partial-model view, manage property set and concept term, create and convert BIM geometric model etc. The paper explored a feasible approach to create and apply BIM and provided theories, methodologies, technologies and platform for building information exchange, sharing and integration management. Furthermore, an integration methodology of 4D technology and operations simulation for construction planning and optimization is proposed and the relative integrated prototype is developed, which verified the proposed BIMIIP and technologies, and formed a more effective method for construction management. This platform adopts C/S structure. C/S architecture adopts two layers of structure, namely composite layer composed of presentation layer and business logic layer, and database access layer. The underlying data are stored by relational database and XML file. The application indicates that the proposed theories and technologies in the paper solved the problem of information silo in different phases and applications in building projects, and laid a foundation for information exchange, sharing and integration in building lifecycle. The proposed BIMIIP possesses a high practical value and application prospect. The user management module is in charge of security and login of the whole platform, including user information adding, deleting, modification and query, and checks the legitimacy of the login user.

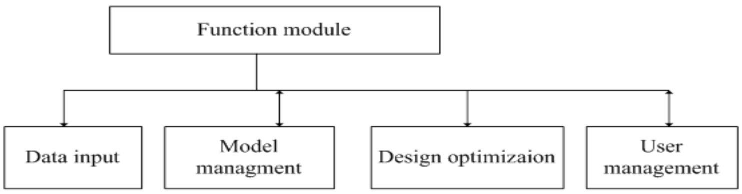

Figure 1: Platform function module partition

3. Optimization method based on grey theory

The analysis of the architectural design parameters and evaluation is to improve the quality of architectural design and the overall performance of the building. Based on the performance-based computer simulation technology and gray correlation decision method and extracting architectural design decisions influencing factors. Grey decision-making is applied to the optimization of construction scheme. Construction scheme evaluation index corresponds to specified construction project, such as economic indicator, quality and safety indicator, construction technical indicator and time limit for a project[. Firstly, decision-making situation is established. The event needing to optimize is a_i and the corresponding decision is b_j, then the situation $S=(a_i,b_j)$. A represents event set and B represents decision set, $S=A\times B$.
For some event i, the situation set is

$$S_i = a_i \times B \Rightarrow \left\{(a_i,b_1),(a_i,b_2),\ldots(a_i,b_j)\right\} \tag{1}$$

Then we should determine objective. Different objective has different extremen value. u_{1j}^{p} represents effective sample of decision sample S_{1j} under objective P . For a specified event, its sample is $\{u_{1j}^{1}, u_{1j}^{2}, \ldots, u_{1j}^{p}\}$. W represents unified measure transformation.

$$W(u_{ij}^{p}) = r_{ij}^{p} \tag{2}$$

$y(n)$ represents sample of behavior n, g^* represents objective.

$$W(y(n), g^{*}) = x(n) \tag{3}$$

$$x(n) = \frac{\min\{y(n), g^{*}\}}{\max\{y(n), g^{*}\}} \tag{4}$$

When P represents middle value objective, W represents moderate effect measure change

$$r_{ij}^{p} = \frac{\min\{u_{ij}^{p}, u(0)\}}{\max\{u_{ij}^{p}, u(0)\}} \tag{5}$$

$u(0)$ represents moderate value. When P represents maximum value objective, W represents upper limit effect measure change.

$$r_{ij}^{p} = \frac{u_{ij}^{p}}{\max_{i} \max_{j} u_{ij}^{p}} \tag{6}$$

When P represents minimum value objective, W represents lower limit effect measure change.

$$r_{ij}^{p} = \frac{\min_{i} \min_{j} u_{ij}^{p}}{u_{ij}^{p}} \tag{7}$$

R represents all the r_{ij}^{p} and G represents all objectives, $G=\{u(\max), u(\min), u(0)\}$.$(G,R)$ represents unified measure space. r_{ij} represents comprehensive effect measure and there are n number of objectives.

$$r_{ij} = \frac{1}{n}\sum_{p=1}^{n} w_{p} r_{i}^{p} \tag{8}$$

w_p represents weight of objective P. For a specified event, $\sum_{p=1}^{n} w_{p} = 1$. Comprehensive effect measure matrix is:

$$\begin{bmatrix} r_{11} & \cdots & r_{j1} \\ \vdots & \ddots & \vdots \\ r_{i1} & \cdots & r_{ij} \end{bmatrix} \tag{9}$$

For a specified event, $(r_{11}, r_{12}, \ldots, r_{1j})$ represents measure space of this event. The decision most suitable to this event is $r_{1j^*}=\max\{r_{11}, r_{12}, \ldots, r_{1j}\}$. S_{1j^*} represents satisfied situation of event one, which means that decision b_j is the best for event a_1. Grey correlation decision theory can be used for optimization of construction scheme, and grey correlation degree can be obtained by establishing the difference space between schemes, so that we can get optimum construction scheme. Value of influence space is given.

$$\begin{bmatrix} w_{1}(1) & \cdots & w_{k}(1) \\ \vdots & \ddots & \vdots \\ w_{1}(p) & \cdots & w_{k}(p) \end{bmatrix}$$

After multiply corresponding weight value, grey correlation factor space is

$$\begin{bmatrix} w_1(1) & \cdots & w_k(1) \\ \vdots & \ddots & \vdots \\ w_1(p) & \cdots & w_k(p) \end{bmatrix}.$$

p represents the number of indicators. For each indicator in the grey correlation factor space, we choose one optimal indicator to form a group, $X_0=\{X_0(1), X_0(2), \ldots, X_0(p)\}$.

$$\Delta_{0i}(y) = |x_0(y) - x_i(y)| \tag{10}$$

$i\in[1,k]$ represents integer, $y\in[1,p]$. The difference matrix is

$$\Delta = \begin{bmatrix} \Delta_{01}(1) & \cdots & \Delta_{0k}(1) \\ \vdots & \ddots & \vdots \\ \Delta_{01}(p) & \cdots & \Delta_{0k}(p) \end{bmatrix}.$$

According to difference matrix, we can get the following parameters

$$\Delta_{0i}(\max) = \max_i \max_y \Delta_{0i}(y) \tag{11}$$

$$\Delta_{0i}(\min) = \min_i \min_y \Delta_{0i}(y) \tag{12}$$

Then grey correlation difference information space set is

$$\Delta_G = (\Delta, \delta, \Delta_{0i}(\max), \Delta_{0i}(\min)). \tag{13}$$

Calculate grey correlation coefficient

$$r(x_0(y), x_i(y)) = \frac{\delta \max_i \max_y \Delta_{0i}(y)}{\Delta_{0i}(y) + \delta \max_i \max_y \Delta_{0i}(y)}. \tag{14}$$

Grey correlation degree is

$$r(x_0, x_i) = \frac{1}{p}\sum_{y=1}^{p} r\left[x_0(y), x_i(y)\right]. \tag{15}$$

Using above formula, we can get $r(x_0,x_1)$, $r(x_0,x_2)$, $r(x_0,x_3)$ and $r(x_0,x_k)$. Compare obtained grey correlation degree; we can get the optimal construction scheme.

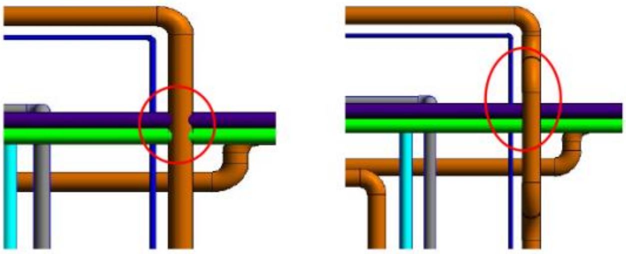

Figure 2: Pipeline collision schematic diagram

4. Construction process simulation optimization based on BIM

A six layer of meeting centre is to be built. BIM is used for auxiliary building, which has not completely been out of the two dimension drawing mode. Based on the two dimension drawing, BIM structure, mechanical and electrical, building model are established for collision check. Three dimensional virtual constructions are used to assist the design and construction. The model is also saved for the operation and maintenance in the late. Pipeline collision schematic diagram is shown in figure 2. Collision detection is to carry out space collision conflict detection for three dimension building information model on the computer in advance. A building is made up of a large number of pipeline, components and equipment. It is designed by different personnel and the task is heavy. The results interference and collision is inevitable between professional. We can carry out collision detection three dimension model before the construction. Then we can find the problem and tag collision point. Through the owner party, we request design unit to change it to avoid cost and human loss due to midway design change.

5. Conclusion

With the rapid development of urbanization in China, the scale of fixed investment assets grow rapidly, thus driving the leap forward development of construction industry. Because the construction process of the building is quite complex, traditional construction methods and models have been unable to meet their requirements. Construction process needs to use computer technology, network technology, virtual reality technology, multimedia technology, three-dimensional digital technology to build computer management system throughout the decision making period, implementation period and operation period. From the aspect of BIM technology, focusing on its visualization, coordination, simulation and optimization, we build a construction project design optimization platform. A system architecture based on C/S is designed in this paper. The corresponding functional test is performed by using the API provided by Revit on Microsoft Visual Studio development platform. This architecture consists of two layers, one is composite layer made up by the presentation layer and the business logic layer, the other is database access layer. On this basis, it makes the optimized function module division, providing basic platform for the realization of the function of the late part. And the practical example is used to testify its validity. The results show that it can reduce construction costs by means of improving construction engineering design efficiency. The results show that this research has higher usage value and application prospect.

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