Application Research on the Integration of Civil Engineering and Computer-aided Building System Based on the Development of BIM

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Abstract. Building informatization and industrialization are mutually advancing in the development process. After BIM technology is widely used in the construction industry, the modeling functions of BIM include standardized components for building building models, "error and leakage collision" inspection, and simulation simulation construction. These functions are in Building industrialization has great advantages in the construction process of prefabricated buildings, especially the standardized design process in the engineering project design stage, which helps to vigorously promote the standardized construction. There is a certain correlation between the improvement of civil engineering construction quality standards and the background of intelligent development. People are more concerned about the quality of engineering projects, and social publicity has been reached for the safety and green environmental protection of buildings. It is imperative to realize technological innovation in civil engineering. The fusion technology of civil engineering technology and computer-aided building system combines building technology, civil engineering technology, control technology, etc. with computer support systems to develop a new type of intelligent building technology. The integration and application of civil engineering and computer-aided building systems are highly valued by the country, which will lead the development direction of the wood construction industry. For colleges and universities, the research and study of the integration and application of civil engineering and computer-aided building systems not only puts forward new requirements for student learning, but also provides new ideas for the direction of employment, and at the same time has a deeper understanding of the relevant research system of universities change. The article mainly explains the working principle of BIM, based on the BIM development background and the integration advantages of civil engineering and computer-supported building systems for specific applications in construction projects, with the goal of promoting the further development and popularization of this technology.

Keywords: BIM; Civil Engineering; Computer-aided Building System; Intelligent Building Technology
1. Introduction
Although traditional construction technology has inherent characteristics and advantages, with the rapid development of science and technology, the integration of BIM-based civil engineering and computer-aided construction systems in modern society represents the new cutting-edge technology in the field of construction engineering. The dominant position and superiority are more prominent [1]. In order to meet people's high requirements for the construction quality of construction projects, meet people's various requirements for architectural design, and improve the quality and efficiency of building construction, using BIM civil engineering and computer-supported building system integration technology, the construction project must be executed [2]. Design and construction use civil engineering and computer-aided building system integration technology to greatly improve the quality of architectural design, including conceptual design, optimized design, computer simulation, construction drawings, rendering and all aspects of architectural engineering. In order to carry out civil construction, the integration technology of civil engineering and computer-aided building systems has been developed into intelligent buildings. As a part of architectural design, architectural engineering design is closely related to architectural projected design. The integration, development and application of civil engineering and computer-aided building systems provide strong technical support for the development of modern architecture [3].

As mankind enters the information age, high-tech technologies such as computers and the Internet are playing an increasingly important role in people's lives. On a global scale, computers have begun to change the way information is produced and used from the date of production [4]. Because with the support of computer software and hardware technology, people can not only use information conveniently, but also create information conveniently. Computer Copy of Architectural Design Architectural technology is the product of the intersection of architectural design science and computer technology [5]. In the teaching and education of civil engineering in colleges and universities, college students must master the use of cutting-edge technology as the main body of education in order to become industry leaders and pioneers. Computer-aided architectural design is an indispensable and important course in civil engineering [6]. The necessity of integrating BIM technology is not limited to the existing computer-aided building system technology education. It should gradually integrate BIM technology education and supporting theories, optimize computer-aided architectural design courses, and strengthen educational content and system reforms. Therefore, in the integration of civil engineering and computer-aided construction technology, the method of realizing BIM curriculum education is the core problem that needs to be solved urgently [7].

The intelligent construction major is based on the civil engineering major, facing the national strategic requirements and the upgrading and transformation of the construction industry, integrating mechanical design and manufacturing automation, electronic information automation, engineering management and other majors to develop into a new engineering major. Recently, the development model of the domestic construction industry has shown an upward trend. In 2016, the total output value of the national construction industry was 19.35 trillion yuan, and the added value of the construction industry was 4.95 trillion yuan. The added value of China's construction industry exceeds that of the United States and ranks first in the world [8]. With the rapid development of the global economy, the construction industry has undergone tremendous development. The scale of construction projects has become larger and larger, the functional requirements of buildings have become more and more complex, and the new technologies for construction are changing day by day. New technologies for construction continue to appear on the scene. , Make the architectural design more scientific and efficient [9]. Nowadays, the country is actively developing industrialization construction, information technology is ubiquitous, and the construction industry has reached an agreement. The main task at this stage is to achieve controllable effects in all aspects and apply BIM technology to engineering projects. Thanks to the support of the integrated application technology of civil engineering and computer-aided building systems, the comprehensive analysis of multiple factors and the comprehensive comparison of multiple plans are no longer difficult, more comprehensive creative thinking, more detailed and more specific architectural design, and more original creation It will no
longer be impossible to optimize the architectural design more efficiently and effectively [10].

2. NURBS Surface Equation

2.1. NURBS Surface Equation

The NURBS surface equation is similar to the expression of NURBS curve. A \( k \times l \) degree NURBS surface also has the following three expression forms.

Rational fraction expression

\[
p(u,v) = \frac{\sum_{i=0}^{m} \sum_{j=0}^{n} \omega_{i,j} N_{i,j}(u) N_{j}(v)}{\sum_{i=0}^{m} \sum_{j=0}^{n} \omega_{i,j} N_{i,j}(u) N_{j}(v) + \delta_{i,j}}
\]  

(1)

The control vertices \( d_{i,j} \) \( (i=0,1,...,m; \ j=0,1,...,n) \) in the above rational fraction expression are an array in a topological matrix, which is \( d_{i,j} \) one-to-one relative to the control vertices. Factors. According to the requirements, the relative weighting factors of the control vertices of the four corners of the control grid must be positive, that is, the other weighting factors are \( \omega_{0,0}, \omega_{m,0}, \omega_{0,n}, \omega_{m,n} > 0 \). \( \delta_{i,j} \) \( \geq 0 \), and the \( k \times l \) weighting factors connected in sequence cannot all be zero. \( N_{i,k} \) \( (u) \) \( (i=0,1,...,m) \) and \( N_{j,l} \) \( (v) \) \( (j=0,1,...,n) \) are the canonical B-spline basis functions corresponding to the \( u \) parameter direction and the \( v \) parameter direction, and They are respectively determined by the \( u \)-to-node vector \( U=[u_0, u_1,\ldots,u_m+k+1] \) and \( v \)-to-node vector \( V=[v_0,v_1,\ldots,v_n+l+1] \) in accordance with the Deboole recursive formula.

Rational basis function expression

\[
p(u,v) = \sum_{i=0}^{m} \sum_{j=0}^{n} \omega_{i,j} d_{i,j} R_{i,j,k}(u,v)
\]  

(2)

Among them, \( R_{i,j,k}(u,v) \) represents the two-variable rational basis function, the specific expression is as follows:

\[
R_{i,j,k}(u,v) = \frac{\omega_{i,j} N_{i,j}(u) N_{j}(v)}{\sum_{i=0}^{m} \sum_{j=0}^{n} \omega_{i,j} N_{i,j}(u) N_{j}(v)}
\]  

(3)

From equation (3), we can see that the bivariate rational basis function cannot be calculated by the product of two univariate functions. Therefore, the NURBS surface is not a tensor product surface. Homogeneous coordinate expression

\[
p(u,v) = H\{P(u,v)\} = \sum_{i=0}^{m} \sum_{j=0}^{n} D_{i,j} N_{i,j}(u) N_{j}(v)
\]  

(4)

\( H() \) in the above formula (4) is the central projection point. Under normal circumstances, the projection center is the origin of homogeneous coordinates. A NURBS surface can be defined as the projection of \( P(u,v) \) on the \( \omega=1 \) hyperplane; \( D_{i,j} = [\omega_{i,j} d_{i,j} \omega_{i,j}] \) called Used as the homogeneous coordinates of the control vertex, or called the weighted control vertex.

2.2. NURBS Surface

Fixed parameters \( u \in (u_i, u_{i+k+1}) \) and \( v \in (V_j, V_{j+l+1}) \), when \( \omega_{i,j} \) taking different values, different points can be obtained:

\[
m = p(u,v, \omega_{i,j} = 0)
\]  

(5)
\[
\begin{align*}
n &= p(u,v,\omega_{ij} = 1) \\
p &= p(u,v,\omega_{ij} \neq 0,1)
\end{align*}
\]

(6)\hspace{1cm}(7)

n and p can be represented by m and \(d_{ij}\) linearly:

\[
n = (1 - \alpha)m + \alpha d_{ij}
\]

(8)

\[
p = (1 - \beta)m + \beta d_{ij}
\]

(9)

2.3. Properties of NURBS Surface Equation

NURBS surface equations are special equations used to generate curves and surface objects. Since the NURBS surface equation is generally defined as more than one curve and surface, it is difficult to generate edges or edge surfaces on the NURBS surface. Due to the characteristics of NURBS surface equations, using NURBS surface equations can carry out a variety of complex surface modeling and expression of special effects. This method has several difficulties in the data exchange process. Exchange operational data on the production platform. Therefore, people need to use special methods in order to explain the shape of curves and surfaces. For this work, the third-order equation aircraft was born. Later, the B-spline was derived from three polynomial aircraft. B-spline is a relatively low-level polynomial spline data set. Later, in order to adapt to more complex data exchanges, B-splines were finally derived, and Nurbs splines were derived from polynomial spline data sets.

3. Modeling Method

3.1. Xgboost Model

The Xgboost model pointed out in the official document given on Github that it can be used on Windows, Linux, OS and other platforms. Its development is written in C++ language, and the underlying writing has a better speed advantage.

The basic principle of the Xgboost model is the same as GBDT, and its objective function is shown in equation (10):

\[
\text{obj}(t) = \sum_{i=1}^{n} \text{L}(y_i \hat{y}_i^{t-1} + f_i(x_i)) + \Omega(f_i) + c
\]

(10)

Equation (10) \(\sum_{i=1}^{n} \text{L}(y_i \hat{y}_i^{t-1} + f_i(x_i))\) is the loss function, \(\Omega(f_i)\) is a regular term, and \(c\) is a constant. The loss function in the equation \(\sum_{i=1}^{n} \text{L}(y_i \hat{y}_i^{t-1} + f_i(x_i))\) is expanded using Taylor expansion as in equation (11):

\[
f(x + \Delta x) \approx f(x) + \hat{f}(x) + \frac{1}{2} \hat{f}'(x) \Delta x^2
\]

(11)

After performing Taylor expansion, the objective function becomes equation (12):

\[
\text{obj}(t) \approx \sum_{i=1}^{n} \{\text{L}(y_i \hat{y}_i^{t-1}) + g_i f_i(x_i) + \frac{1}{2} h_i \hat{f}_i(x_i)\} + \Omega(f_i) + c
\]

(12)
In formula (12):

\[ g_i = f'(x) = \frac{\partial L(y, \hat{y}^{t-1})}{\partial \hat{y}^{t-1}} \]

(13)

\[ h_i = f''(x) = \frac{\partial^2 L(y, \hat{y}^{t-1})}{\partial \hat{y}^{t-1}} \]

(14)

The \( \Omega(f_l) \) positive term in formula (12) is:

\[ \Omega(f_l) = \gamma T + \frac{1}{\gamma} \sum_{i=1}^{T} w_i^2 \]

(15)

In formula (15), \( T \) represents the number of leaf nodes of the tree, and \( W \) represents the weight on the leaf node, which is the weight on the leaf node, \( \lambda \) and \( \gamma \) both are hyperparameters. Equation (15) can be known as known \( \lambda(y, \hat{y}^{t-1}) \), so it can be melted into the constant term and treated as a constant, so continue to simplify the objective function to:

\[ \text{obj}(t) \approx \sum_{i=1}^{n} \left\{ g_i f_i(x_i) + \frac{1}{\gamma} h_i w_i^2 \right\} + \Omega(f_l) + c \]

(16)

At the same time, formula (15) is incorporated into the objective function formula (16) to obtain formula (17):

\[ \text{obj}(t) \approx \sum_{i=1}^{n} \left\{ g_i f_i(x_i) + \frac{1}{\gamma} h_i w_i^2 \right\} + \gamma T + \frac{1}{\gamma} \sum_{i=1}^{T} w_i^2 + c \]

(17)

3.2. Light GBM Model

The Light GBM model was open sourced by Microsoft in 2017. It has the same properties as Xgboost and belongs to the gradient boosting tree.

After the objective function is dimensionally transformed, formula (18) can be obtained:

\[ \text{obj}(t) = \sum_{j=1}^{T} \left[ (\sum_{i \in I_j} g_i) w_j + \frac{1}{\gamma} (\sum_{i \in I_j} h_i) w_j^2 \right] + \gamma T + \frac{1}{\gamma} \sum_{i=1}^{T} w_i^2 + c \]

(18)

In formula (18), where is the number of samples, \( D \) is the number of leaf nodes of the tree, after formula (18), the dimension is converted, and then simplified formula (18) can be obtained:

\[ \text{obj}(t) \approx \sum_{j=1}^{T} \left[ (\sum_{i \in I_j} g_i) w_j + \frac{1}{\gamma} (\sum_{i \in I_j} h_i) w_j^2 \right] + \gamma T + c \]

(19)

Simplified formula (19) can be obtained:

\[ J(f_i) = \sum_{j=1}^{T} \left[ G_j w_j + \frac{1}{\gamma} (H_j + \lambda) w_j^2 \right] + \gamma T + c = -\frac{1}{\gamma} \sum_{j=1}^{T} \frac{G_j^2}{1 + H_j + \lambda} \]

(20)

The simplified objective function equation (20) is obtained, and the first derivative of the objective function is obtained, and then:
\[
\frac{\partial J(f_i)}{\partial w_j} = G_j + (H_j + \lambda)w_j
\]

(21)

Let the derivative be 0 is the extreme point of the objective function that you want to obtain after simplifying, you can get equation (22):

\[w_j = -\frac{G_j}{H_j + \lambda}\]

(22)

Through the first-order derivative, second-order derivative and other hyperparameters of the loss function, the leaf nodes can be obtained, which completes the simple operation of complex calculations. Through the above simplified operations, we can know that there is no need to perform too many calculations during iteration.

4. Evaluation Results and Research
The Light GBM official website shows that its performance is better than the Xgboost algorithm. It belongs to the fast boosting algorithm in recent years. Light GBM is a search strategy from another angle. The two methods have different control strategies and cannot be said to be complementary models. But it can be said that it is a more diverse model, which can increase the ability of the overall model after combination. After our experimental investigation and analysis, we measured the running speed comparison and memory ratio comparison chart of Light GBM model and Xgboost model (Figure 1, Figure 2).

![Figure 1](image_url)

**Figure 1.** Comparison diagram of running speed between LightGBM model and Xgboost model (unit: s)
From the data in the two figures, it can be clearly seen that the LightGBM model is faster than the Xgboost model for architectural design, has higher efficiency, smaller memory footprint, lower communication overhead between parallels, and higher accuracy, and it has the advantages of one-hot transformation. A large number of sparse features generated afterwards have good processing capabilities and can handle large-scale data. And according to experiments, it is a modern technological intelligent building technology developed by the integration of civil engineering technology and computer-aided building system technology. Establishing the LightGBM model for engineering construction can make it more convenient for the construction contractor to establish an ideal, scientific, reasonable and effective construction design method more quickly and effectively.

First of all, LightGBM no longer uses the traditional pre-sorted algorithm. The pre-sorted algorithm needs to store the characteristic value of the data and save the result of the characteristic arrangement. It needs to consume twice the memory of the learning data, so the speed will be slower. Xgboost is a method that is used repeatedly, requiring multiple browsing of all data. If all data is stored, memory pressure will increase and limit. If all are not stored, repeat reading and writing training. Data will waste more time.

|                  | Light GBM model | Traditional model |
|------------------|-----------------|-------------------|
| Correct rate     | 96.2%           | 63.5%             |
| Rate of return   | 59.6%           | 33.5%             |

It can be seen from the table that the technology LightGBM model obtained after the integration of civil engineering and computer-aided construction has a much higher accuracy rate for the pre-project design prediction calculation than the traditional prediction technology. The LightGBM model used after the use of the fusion technology can greatly reduce the unpredictable conditions caused by the construction of the project, and can also obtain higher benefits, so as to achieve the most efficient engineering benefits.
5. Conclusion
With the continuous use of computer technology, applying it to architectural design to play an auxiliary function can realize project layout and project system planning procedures, and promote the improvement of design efficiency. In construction engineering, the application of BIM-based civil engineering and computer-aided construction system integration technology has many advantages, which is of great significance to promote the innovation and reform of construction technology and promote the rapid development of the construction industry. However, social needs continue to change, technology continues to develop, and the construction industry continues to develop. Therefore, the fusion technology of civil engineering and computer-aided building systems based on BIM should adapt to the times, with the development of the times, continuous improvement and optimization, adapt to and meet the requirements of construction projects. The integration technology of civil engineering and computer-aided system has introduced multi-faceted information and multi-faceted computer-aided technology from the early stage of design talent training, which has high practical value and feasibility. Continuously improving the efficiency and quality of engineering design, the continuous development of world social information and the continuous increase of computer network users, civil engineering and computer support construction technology will find better design methods and optimization methods for solving problems.

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