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Application of BIM in the Design and Construction of Fabricated Buildings

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Abstract. The impact of safety accidents is very serious, which will not only cause the loss of economic benefits of the project, but also harm the life safety of participants in the building site, and at the same time affect the image of construction-related enterprises and the growth of the industry. BIM as a global and digital technology, is regarded as a revolution in the building industry, which can effectively improve the building efficiency and quality. In this article, a risk assessment model of prefabricated buildings based on artificial neural network (ANN) and BIM is proposed, which can provide early warning and assessment of construction risks, so as to build a safe construction environment and provide theoretical and technical support for the design and construction of prefabricated buildings. The results show that, after many iterations, the accuracy of this method is 97.94%, which is 18.66% higher than that of particle swarm optimization (PSO), and the error is reduced by 33.75%. This algorithm solves the difficulties that traditional models are difficult to deal with highly nonlinear models and lack of adaptive ability. A reasonable safety assessment system can help constructors understand the safety management problems faced in the construction of prefabricated buildings and make accurate judgments.

Keywords: Assembled Building; Construction Risk; Artificial Neural Network; Building Information Model.
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1 INTRODUCTION

Due to the needs of social construction and development, there are more and more projects with relatively large investment, and the scale of construction is constantly expanding. Not only the structure of the project, but also the environment of the project itself is becoming more and more complicated [1]. From the statistical data analysis, the probability of safety accidents in the construction industry is the highest, and the construction environment of the building site is complex, resulting in many safety influencing factors. As one of the four goals of the safety construction industry, it is also the most important goal [2]. In the construction industry. This construction mode is based on the informatization, intelligence and industrialization of buildings, so as to achieve the goals of standardized design, intelligent industrial production, efficient information circulation, lean production management and controllable production cost in the whole building stage

There are many technical links in prefabricated buildings, which require workers' professional and refined construction technology. Besides the falling accidents of buildings in the traditional sense, there are also many safety accidents such as vehicle injuries, object strikes, lifting injuries, mechanical injuries [3], etc., which face very complicated safety problems. In terms of the environment, the dust and noise in the building site are serious, which also damages the ecology. The requirements of China for the green growth of construction industry, and it has become an obstacle to the rapid growth of construction industry in China. How to transform the construction industry has become a key issue for the growth of construction industry in China [4]. The impact of the accident is very serious, which will not only cause the loss of economic benefits of the project, but also harm the life safety of the participants in the building site, and at the same time affect the image of construction-related enterprises and the growth of the industry. As a global and digital technology, BIM is regarded as a revolution in the construction industry. Moreover, the limited land resources and high land costs make the building height constantly rising, and prefabricated buildings are more sustainable in the economic, environmental and social aspects, and become an effective method to solve this problem with their clean, safe and high-quality characteristics [5]. In this article, a risk assessment model of prefabricated buildings based on ANN and BIM is proposed, which can warn and assessed the construction risks, so as to build a safe construction environment and provide theoretical and technical support.

In this paper, the risk assessment of building assembly is carried out with the aid of computer. The main innovations include the following.

(1) This paper analyzes the significance and development of safe processing in the process of building assembly, and analyzes the current situation of building assembly based on BIM through artificial intelligence algorithm aided design.

(2) In this article, ANN is used to construct the early warning model of prefabricated building construction risk, so as to enrich the basic theory of early warning of construction risk, and improve the ability of preventing and resolving construction risks and management efficiency.

The first section of the article is the introduction, which introduces the background and significance of the construction risk of prefabricated buildings, and puts forward the construction risk early warning and assessment model with the help of ANN and BIM. The second section is the related work, which analyzes the scholars' research on the field of construction risk and puts forward the research innovation of this article. The third section is the theory and method part. Firstly, the present situation of construction environment and risk analysis of prefabricated buildings is analyzed, and an early warning model of prefabricated buildings construction risk is built based on ANN. The fourth section is the result analysis and discussion, and the simulation experiment proves the effectiveness of the construction risk analysis method in this article. The fifth section is the conclusion, which summarizes the contribution of the research to the field of prefabricated building construction, and puts forward the limitations of this article and the future research direction.

2 RELATED WORK

Throughout the research on the safety risks of prefabricated buildings, it is found that most of the risk identification is still at the level of qualitative analysis, and the risk assessment index system is too dependent on the traditional buildings in the past and lacks data support.

In the process and analysis of safety inspection and operation of civil engineering structures, it is inseparable from the design of mine safety monitoring system and the operation and maintenance of equipment. Be familiar with the working principles of various detection and monitoring equipment; Master the composition of the safety monitoring system, and analyze the performance characteristics of common detection equipment and monitoring system. Sampaio [6] describes the installation and setup of building monitoring system software. According to the specific safety problems and requirements, a feasible technical scheme for safety detection and monitoring is proposed. Equipment selection, installation, commissioning and maintenance shall be carried out. At the same time, the operator shall be familiar with the operation and analysis of occupational health and safety detection, be able to design drawings, connect and adjust hardware, and monitor correctly. Sędzicki et al. [7] believes that the emergence of computer aided architectural design has brought certain vitality and vitality to the construction industry. It has promoted the continuous development of the construction industry, but with the further development of the times, computer aided architectural design has been far from meeting the needs of the society for the construction industry. Wang's [8] believes that with BM software, architects can have a lot of time to design buildings. Relying on BIM software, the quality of architectural design is greatly improved, the required time is shortened, and the work efficiency is improved. Computer aided generation of intuitive and vivid three-dimensional models. This makes the communication between architects and others more convenient. Wang et al. [9] believes that with the development of BM technology, computer aided building energy-saving design has great advantages. BM software architect can quickly and accurately evaluate the energy consumption of the designed building at any time, and reasonably adjust the scheme according to the data analysis results. Therefore, accurate and intuitive information about building energy consumption can be obtained at the early stage of building design. Zhao [10] believes that the use of computer assistance can identify the attribute information and component parameters of each building component unit. The above attribute information and component parameters are identified respectively to realize the detection of the above building model. Its detection scheme can cover all parts of the building model, and can conduct more comprehensive detection, which improves the accuracy of building model detection and the corresponding detection effect.

At present, most of the research still stays in the theoretical knowledge of analyzing risk types and preventing risks, and the research on risk early warning of prefabricated building construction needs to be further expanded. Based on the knowledge and principles of ANN and BIM, this article applies them to the risk assessment of prefabricated construction, and establishes an early warning model of prefabricated construction risk based on ANN. The simulation results show that the results obtained by ANN model are satisfactory.

3 METHODOLOGY

3.1 Assembled Building and Its Construction Characteristics

Build an information management platform integrating information technology and communication technology, build a communication bridge for information islands, and form information interaction. With the help of this platform, all participants can work together, mobilize the enthusiasm and initiative of all participants, and promote the project management to change from passive control and information islands to active control and integrated management. The concrete structure formed by the proper and safe connection of precast concrete members is called precast concrete structure, which can be referred to as prefabricated building for short in construction engineering. Therefore, the traditional linear model can't accurately reflect the internal relationship between safety assessment and influencing factors, which leads to the failure to meet the requirements of high-precision assessment. From the local to the whole, from micro to macro, the industry construction mode has gradually changed from digital construction to information construction. The main components of BIM are shown in Figure 1.

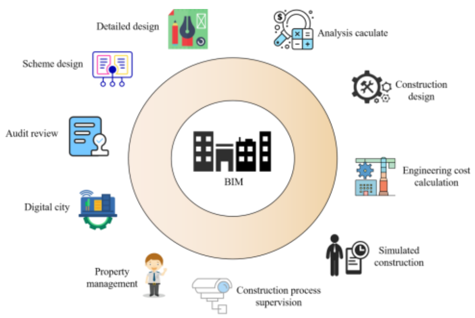


Figure 1: Main components of BIM.

For the safety assessment of prefabricated buildings, an effective, scientific and practical method is needed, which can effectively overcome the complex and uncertain characteristics of safety degree and its influencing factors, so as to meet the requirements of high precision. There are many indexes in the construction safety assessment model, and there is a nonlinear relationship among the safety factors. Based on the ability of ANN to handle nonlinear mapping and high-speed calculation, it can establish a dynamic and stable learning system according to its own learning and adaptation, so as to optimize and adjust the model and quickly find the global optimal solution.

3.2 Pre-Warning Model of Assembled Building Construction Risk

Prefabricated building construction is a stage of pattern identification and classification. Compared with the traditional construction industry, prefabricated building construction has higher risks. Therefore, the early warning mechanism should be continuous and dynamic. ANN can recover the complete information contained in the original data index through pre-stored information and self-adaptive training by learning mechanism. Then, the sample data to be predicted or tested is input into the model, and the data judgment result is obtained. The principle of ANN is shown in Figure 2.

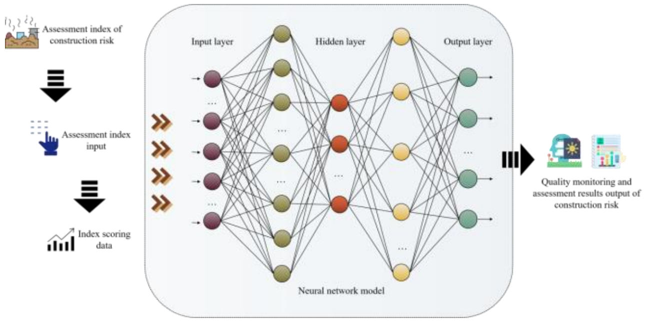


Figure 2: ANN principle.

By averaging the pixels in the BIM graphic template, the pixel (x, y) to be processed is replaced by the average value obtained, and the gray value of the pixel to be processed is $g(x, y)$, that is:

$$g(x,y)=\frac{1}{N}\sum_{f\in I} f(x,y) \tag{1}$$

Where, the total number of all pixels in the template is N, and the weighted average of the template is usually calculated to keep the gray value of the processed pixels consistent with that of the original pixels.

The following formula is used to describe the risk minimization function of the model structure:

$$\beta=\min\sum_{i=1}\left(f(x)-y\right)^2+\alpha\|\theta\|^2 \tag{2}$$

The linear transformation function input by the image is expressed as:

$$\partial=\sum_i \beta_i\omega(x_i) \tag{3}$$

The coefficient ω vector can be used to represent the weight ∂ value. In the task of target detection using correlation filter function, the characteristic sample of image information is usually taken as the input variable, and the kernel function involved is expressed as:

$$\theta=\theta(x_i,x_j) \tag{4}$$

The input image is detected by the filter generated after training, and the building image information is calculated and displayed in response to the calculation:

$$f(y)=\sum\beta_i\theta(y,x_i) \tag{5}$$

After calculating the response values of architectural image features, the matched architectural semantic features can be updated by filters.

$$X=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}=\left(X_{ij}\right)_{m\times n} \tag{6}$$

Where $X_{ij}(i=1,2,\ldots,m;\ j=1,2,\ldots,n)$ is the index characteristic quantity of the i assessment factor of the j scheme. Calculate the set-valued statistical value x_{ij} of the i index of the j scheme with the following formula, namely:

$$X_{ij}=\frac{1}{2}\sum_{k=1}^{n}\left[\left(x_{2ij}{}^{(k)}\right)^2-\left(x_{1ij}{}^{(k)}\right)^2\right]/\sum_{k=1}^{n}\left[\left(x_{2ij}{}^{(k)}\right)-\left(x_{1ij}{}^{(k)}\right)\right] \tag{7}$$

Define the intensity of ANN as the expectation of edge function:

$$s=E(mr(X,Y)) \tag{8}$$

The strength of the ANN classifier is estimated as:

$$s=\frac{1}{n}\sum_{k=1}^{n}\left[Q(X_i,Y)-\max_{\substack{j\neq Y\\ i=1}} Q(X_i,j)\right] \tag{9}$$

Then the correlation between decision trees is:

$$\bar{\rho} = \frac{\operatorname{var}(mr)}{sd(h(*))^2} = \frac{\frac{1}{n}\sum_{k=1}^{n}\left[Q(X_i,Y) - \max_{\substack{j\neq Y\\ i=1}} Q(X_i,j)\right]^2 - s^2}{\left(\frac{1}{k}\sum_{u=1}^{k}\sqrt{p_u + \bar{p}_u + (p_u - \bar{p}_u)^2}\right)^2} \tag{10}$$

$$p_u = \frac{\sum_{(x_i,y)\in O_i} I(h(x_i) = y)}{\sum_{(x_i,y)\in O_i} I(h(x_i))} \tag{11}$$

$$\bar{p}_u = \frac{\sum_{(x_i,y)\in O_i} I(h(x_i) = y_j)}{\sum_{(x_i,y)\in O_i} I(h(x_i))} \tag{12}$$

Where p_u represents the correct classification ratio of data samples outside the bag; $\bar{p}_u$ indicates the proportion of y_j in the data samples out of the bag that are wrongly classified into multiple categories. $sd(h(*))^2$ is the square of the standard deviation of ANN classifier, and $\operatorname{var}(mr)$ is the variance of edge function.

$$U = \{u_1, u_2, \ldots, u_m\} \tag{13}$$

$$V = \{v_1, v_2, \ldots, v_m\} \tag{14}$$

Perform fuzzy judgment on each factor in U according to the grade indicators in the judgment set, and get the judgment matrix:

$$R = (r_{ij})_{n\times m} \tag{15}$$

Among them, r_{ij} represents the affiliation degree of u_i with respect to v_i. After determining the importance index of each factor, record it as:

$$A = \{a_1, a_2, \ldots, a_m\}, \quad \sum_{i=1}^{n} a_i = 1 \tag{16}$$

Synthesized to:

$$\bar{B} = AR = (\bar{b}_1, \bar{b}_2, \ldots, \bar{b}_m) \tag{17}$$

After normalization, the following results are obtained:

$$B = \{b_1, b_2, \ldots, b_m\} \tag{18}$$

Therefore, the construction risk assessment level of the assessment object can be determined.

4 RESULT ANALYSIS AND DISCUSSION

All the statistical data have a certain degree of error, so in order to reduce the error, we can make multiple comparisons and compare the samples from different angles. Quantitative data with large differences in data distribution intervals are treated with interval discretization. Data outlier removal processing is shown in Figure 3.

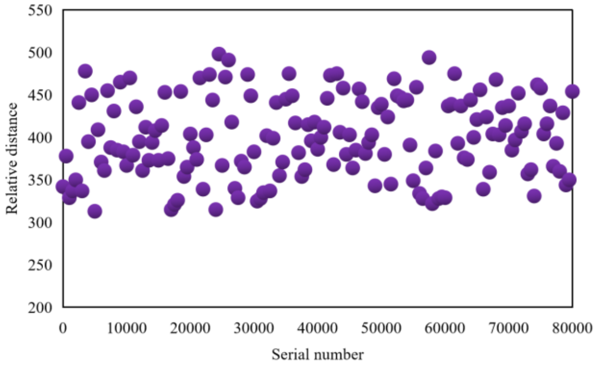


Figure 3: Data outlier removal processing.

Using these data to train the designed ANN can get better network weights. Then, the obtained network weights can be substituted into ANN, which can become the basic model of prefabricated building construction risk assessment. A large number of interconnected network structures in the ANN model can process large-scale data in parallel, realize global real-time information analysis, and quickly coordinate the relationship of various input information for a specific problem, so that the global optimal solution can be quickly found by using high-speed computing power.

The assessment of construction project risk by neural network requires a certain number of known samples as training sets to train the neural network, and then the project to be assessed can be assessed. The training sample set of the network is generally the authoritative assessment result with high credibility, and they can be obtained by experts' assessment of the actual operation results of a few typical prefabricated building construction projects. For the project to be assessed, as long as the experts give the value of each risk index, the neural network assessment system can be used for comprehensive risk assessment, and the assessment score is given by the output layer. Compare the output data of ANN with the real fabricated building construction data, as shown in Figure 4.

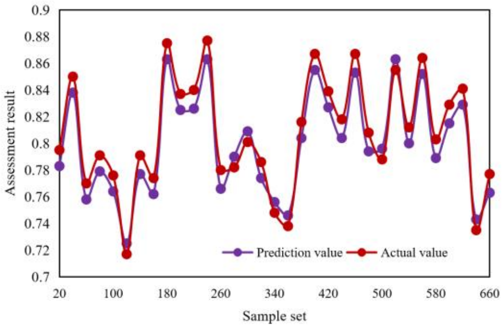
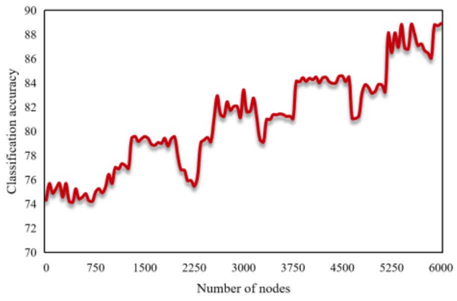


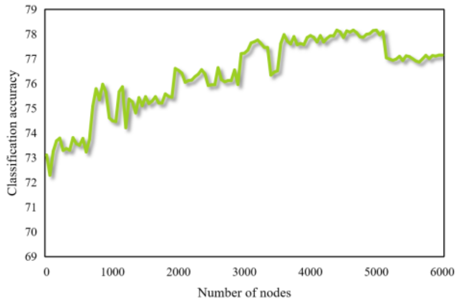
Figure 4: ANN learning results.

It is not difficult to see that the results of ANN learning can approximate the original data very well, and it has the basis for forecasting the risk data. In the safety assessment model of prefabricated buildings, the aspects and data involved are huge, which requires this characteristic of ANN to speed up the solution of the model and improve the accuracy of the model.

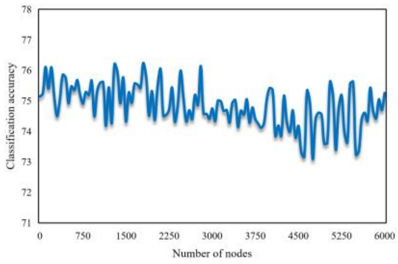
The accuracy of different risk early warning algorithms in prefabricated building construction management is shown in Figure 5.



(a) ANN.



(b) PSO.



(c) GA.

Figure 5: Prediction accuracy of different algorithms in construction management of prefabricated buildings.

Based on the analysis of safety accident factors in the building site of prefabricated buildings, after determining the participation factors in the building site, the next influencing factors related to the participation factors are further established. Taking the recall of prefabricated building construction risk prediction as the test index, and selecting traditional PSO and GA as the contrast objects, the experimental results are shown in Table 1, Table 2 and Table 3.

Sample size	Forecast risk recall (%)
15	97.65
30	95.79
45	94.36
60	92.55
75	92.17
90	91.55
105	90.85

Table 1: Recall of assembled building construction risk prediction by ANN.

Sample size	Forecast risk recall (%)
15	92.11
30	89.2
45	88.18
60	85.24
75	79.36
90	75.88
105	71.84

Table 2: Recall of assembled building construction risk prediction by PSO.

Sample size	*Forecast risk recall (%)*
15	89.67
30	87.43
45	83.11
60	77.89
75	75.28
90	71.33
105	69.85

Table 3: Recall of assembled building construction risk prediction by GA.

According to the experimental data, when the number of test samples starts to increase, the risk prediction recalls of different analysis methods all show a downward trend. However, compared with traditional PSO and GA, the risk prediction recall of this method is obviously higher. As a nonlinear system with large-scale parallel processing, which is modeled according to the intrinsic relationship of the data itself. Comparing the accuracy and average absolute error between the building risk identification model and PSO in this article, the results are shown in Figure 6 and Figure 7.

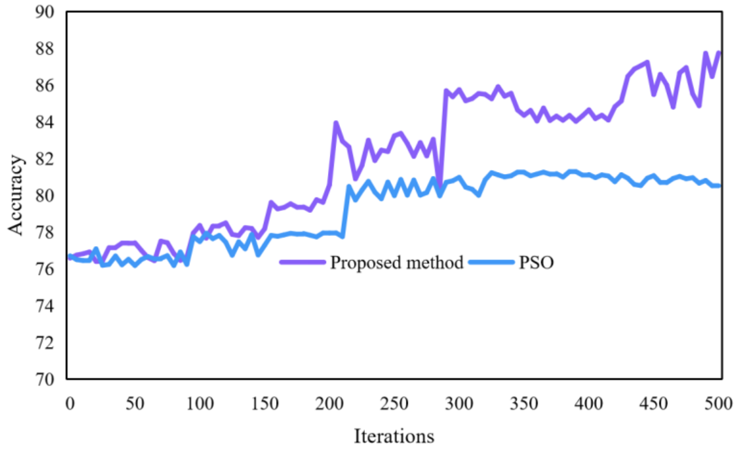


Figure 6: Accuracy comparison.

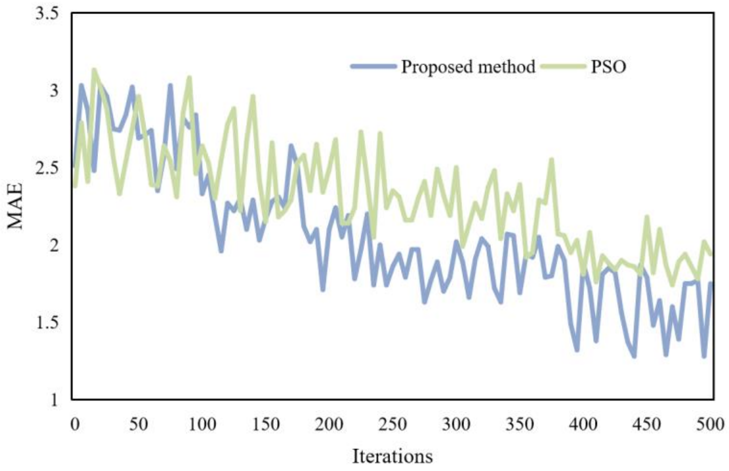


Figure 7: Comparison of average absolute error.

As can be seen from Figure 6 and Figure 7, after many iterations, the accuracy of this method reaches 97.94%, which is 18.66% higher than that of PSO, and the error is reduced by 33.75%. Therefore, the risk assessment model of prefabricated building construction based on ANN is a reasonable and feasible assessment model, which is of great significance to the construction of safe construction environment. As the growth of prefabricated buildings is relatively immature compared with that of foreign countries, the safety laws and regulations supporting them need to be improved. Enterprises should improve their safety rules and regulations ensure their effective implementation. The management should know BIM knowledge and master certain BIM technical skills and application experience. Mature BIM management experience can promote the control of the building site process and ensure the construction progress and safety during the building stage.

5 CONCLUSIONS

The concept of BIM technology is in line with the refined and industrialized characteristics of the fabricated structure industry, and combines the two organically, so that BIM technology can be applied and innovated in the construction of fabricated structures, solve the difficulties in the stage, and accelerate the growth. This model can dynamically simulate the safety state of prefabricated buildings, and reduce the impact of uncertainty and index interaction. After several iterations, the accuracy of this method reaches 97.94%, which is 18.66% higher than PSO algorithm, and the error is reduced by 33.75%. The advantages of self - learning and self - feedback of neural network and the simulation of nonlinear multi - index model make this method have practical application value.

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