Real time cost control algorithm of complex construction project based on BIM

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Abstract. The existing project cost control algorithms do not consider the task coupling characteristics in the project cost, and the calculation is easily affected by the coupling, resulting in a large mean square error. Therefore, a BIM based real-time control algorithm for complex construction cost is proposed. Firstly, BIM method is used to optimize the allocation of engineering resources. Secondly, considering the coupling of tasks in project cost, demand side management structure is used to decouple. Then, the equivalent approximate control model is established to calculate the cost factors to realize the cost control of the project. In order to verify the feasibility of the design algorithm, the simulation results show that the control response of the design algorithm is higher, and the root mean square error is lower, which meets the original intention of the design.

1. Introduction
At present, the complexity of construction engineering is increasing, and the process and related steps are also increased, which leads to the increase in factors affecting the cost of the project [1-3]. However, most of the current domestic and foreign researchers on the cost control algorithm of construction engineering costs are based on the algorithm established by neural network technology [4-5]. However, with the increase of influencing factors, coupling often occurs, which affects the operation ability and accuracy of the algorithm. However, BIM method is usually applied in project management, which can adapt to construction resource allocation management and cost monitoring. Therefore, it is feasible to apply BIM method in real-time cost control algorithm of loaded construction projects [6-7].

2. Design of real-time control algorithm for complex construction cost based on BIM

2.1. Resource allocation optimization of BIM project
In the process of engineering development, it is easy to increase the cost of resources due to the lack of uniform distribution of engineering resources. The more complex the project is, the more likely the problem will appear [8-9]. In this paper, the balanced allocation model of engineering resources is established to solve this problem.

Under the construction resources of type $k$, the daily demand is $R_k$, then the formula is:
In formula (1), $T$ represents the total construction period (days) of the project, and $R_{jk}$ represents the demand of the type of $k$ construction resources in the process $j$. In the construction process, the standard deviation of uneven resources caused by some reasons is $\sigma_k$, then the formula is:

$$\sigma_k = \sqrt{\frac{1}{T} \sum_{i=1}^{T} \left( R_{jk} - \bar{R}_k \right)^2}$$  \hfill (2)$$

After determining the above parameters, BIM method is used to solve and optimize the parameters. Firstly, the initial population of engineering form in BIM mode is confirmed, and a random method is used to generate the initial population of engineering form $j$ in the logical relationship between processes. The start time of operation is $T_{S_j}$, and in BIM, the initial population is carried out from the last process to the first process. The set of work $j$ set after the process is $B_j$, and the gene of the process $j$ is:

$$g_j = ES_j + \text{random} \left\{ \min \{ g_k \mid k \in B_j \} - D_j - ES_j \right\}$$  \hfill (3)$$

In formula (3), $ES_j$ represents the earliest scheduled start time of the operation $j$ and $D_j$ represents the duration of the operation $j$. In order to obtain the best resource allocation pattern, we need to obtain the objective function within the population, which can be obtained by sorting the data. In this paper, ranking function is used to sort. The expression of fitness function is as follows:

$$\text{FitV} = \text{ranking} \left( \text{ObjV} \right)$$  \hfill (4)$$

After obtaining the function, the single point crossover operator is used, and the actual time of the operation $j$ will be affected by the subsequent operation. The cross operation needs to be verified for each individual. The verification is carried out from the back to the front, the formula is:

$$g_j \leq \min \{ g_k \mid k \in B_j \} - D_j$$  \hfill (5)$$

When an individual needs to satisfy the verification condition in (5), when the individual does not meet the verification condition, then (3) is used to reassign the value. The amplitude of formula (5) is used to ensure the range of variable time difference corresponding to the random gene, and the gene position of chromosome is determined, and the individual value of resource demand in the process is solved. BIM method is used to calculate the resource allocation of construction projects to control the cost loss caused by poor allocation.

2.2. Cost task coupling decoupling

In complex building construction, there are many process tasks in design, and task coupling is easy to occur in process engineering task planning [10]. Considering the characteristics of complex building construction, this paper uses DSM dependent structure matrix to decouple the coupling tasks in engineering. As shown in figure 1.
In engineering activities, it is assumed that the project contains \( n \) engineering activity tasks \( A_i (i = 1, 2, ..., n) \), and the elements \( a_{ij} \) in the matrix representing the dependencies of engineering tasks.

The matrix in Figure 1 reflects the relationship between all tasks in a project, and the relationship can be divided into three forms. It is:

- The project \( a_{ii} = *, i = j \) represents itself, on behalf of the engineering task, while \( A_j \) not providing information on the task \( A_i \), it means that the engineering task \( a_{ij} = 0, i \neq j \) replacing \( A_j \) provides information to the engineering task \( A_i \). In this way, the corresponding engineering task execution structure is established as shown in figure 2.

In the DSM structure of Figure 2, the element value is only set to 0 or 1, which reflects the strength of the dependency relationship between different engineering tasks depending on the difference of element values. And the three structures \( a_{ij} = *, i = j \), \( a_{ij} = 0, i \neq j \) and \( a_{ij} \neq 0, i \neq j \) are used to decouple the different engineering tasks, and the work tasks are planned according to the work task connection relationship in Figure 2. To avoid the cost loss caused by poor project planning.

2.3. Equivalent approximate control model

After realizing the cost control of resource allocation and project task planning, it is necessary to control the cost economy of the project. The equivalent approximate control model is established to control the cost economic index. The phase space reconstruction vector trajectory matrix of project cost budget growth index is shown as formula (6).
In formula (6), \( m \) represents the embedded dimension in the matrix, the price cost of engineering materials is represented by \( g \), and \( D \) is the period of time series in the matrix, and the decomposition of \( L = U \times S \times C \) is the factor grey correlation of the matrix, where \( S \) and \( C \) represent singular values, and \( U \) and \( C \) decomposed by matrix \( L \) represent orthogonal matrix. Matrix \( C \) represents:

\[
C = (c_1, c_2, ..., c_n)
\]

(7)

In formula (7), \( C \) represents the constant in the matrix. In the orthogonal matrix, redundant information will appear, and the redundant information needs to be further filtered. The filtering process is shown as formula (8).

\[
S = \text{diag}(\sigma_1, \sigma_2, ..., \sigma_n), \sigma_1 \geq \sigma_2 \geq \sigma_n \geq 0
\]

(8)

In formula (8), \( \sigma \) represents the redundant information generated, and \( S \) can be used as the filtered information. At the same time, set an estimated value to calculate the matrix, the estimated value is \( \phi x_{i+1} \approx \hat{X} \phi x_i \). Where \( \phi x_i = x_j - x_i \) represents the variation of quality benefit control in the project. The vector \( x_j \) is used as the adjacent quality benefit control vector of \( x_i \). At the same time, \( x_j \) is set to a subset of the set \( R^n \). If the historical value of the cost of complex construction project is \( \{x_i\}_{i=1}^N \), then there is the relationship between \( \phi x_{i+1} = x_{j+1} - x_{i+1} \) and the corresponding solutions of \( \phi x_{i+1} \) and \( \phi x_i \) are calculated respectively. After obtaining the solution value, the matrix parameter data in formula (6) is obtained, and the estimated value is obtained. The cost economic data of the project is obtained by using the estimated value, and the optimal cost economic data of the project cost is obtained. Realize the cost control calculation.

3. Analysis of simulation experiment

In order to prove the effectiveness of the algorithm designed in this paper, the algorithm is simulated by MATLAB6.5 environment to simulate the cost of complex construction project, and the experimental platform of project cost control is established. The cost control algorithm in this paper and the cost control algorithm in literature [1], document [2] and document [4] are used for comparative experiments.

3.1. Simulation environment

In this paper, the PC host configuration is as follows: the host processor model is i59400f, the TDP power is 65W, the interface type is Intel LGA 1151, the number of cores is six, and the main frequency is 2.9 GHz. The memory module model is BLS8G4D240FSC, the memory capacity is 8GB, and the memory frequency is 3600 MHz. The display card model is RX560D 4GB D5, and the video memory capacity is 2GB. The hard disk model is WD10EZEX, the hard disk capacity is 1 TB, and the revolution is 7200 rpm.

3.2. Comparison of real-time cost control effect

In order to reflect the advantages and disadvantages of the algorithm, this paper compares the control response of the four methods and the root mean square error of cost control as the evaluation standard. The comparison results of control responsiveness are shown in figure 3.
Fig. 3 Control responsiveness comparison of cost control algorithm

In Figure 3, algorithm 1 is the cost control algorithm designed in this paper, algorithm 2 is the cost control algorithm in reference [1], algorithm 3 is the cost control algorithm in reference [2], and algorithm 4 is the cost control algorithm in reference [4]. From Figure 2, it is found that in the cost control algorithm designed in this paper, the control responsiveness of the cost control algorithm designed in this paper increases with the input of experimental data. However, when the data reaches a certain degree, the control response of the algorithm does not change significantly and is close to the given control threshold. The control response of other algorithms increases with the increase of data, while the response of the other three algorithms is usually less than 40%, which shows that the control response of this algorithm is better than that of other algorithms. The comparison of mean square error of the four algorithms in cost control is shown as figure 4.

Fig.4 Comparison Chart of root mean square error of cost control algorithm control

It can be seen from figure 4 that the root mean square error of the three algorithms increases with the increase of data volume in the experiment. The root mean square error of algorithm two is 22.5% when the data volume is 100, and the root mean square error of algorithm three is increased to 18.7% when the amount of data is 100. The root mean square error of algorithm 4 is increased to 26.7% when the amount of data is 100. The root mean square error of this algorithm is less affected by the increase of experimental data, and the error is always kept below 5%. According to the experimental results in Fig. 3 and Fig. 4, the performance of the real-time cost control algorithm designed in this paper is better, and the algorithm is feasible.
4. Conclusion
In this paper, the BIM method is used to optimize the allocation of engineering resources, and the equivalent approximate control model is used to control the cost. However, the cost of this kind of optimization is still not considered in this paper.

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