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Research on the whole life cycle simulation of the ancient architecture of bim technology

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Abstract. BIM technology is often used in the maintenance and maintenance of ancient buildings. In order to explore the application effect of BIM technology in the life cycle simulation of ancient architecture, a full life cycle simulation algorithm (FFCSA) integrating BIM technology is proposed. Through the simulation of the life cycle of ancient buildings, a complete BIM system for the maintenance and maintenance of ancient buildings is formed. So as to change the recording mode of the traditional ancient buildings maintenance and maintenance, and further meet the custom time sequence of the whole life cycle plan of ancient buildings. The simulation results show that the BIM technology can be used effectively in the protection of ancient buildings.

Key words. BIM technology model, Ancient buildings, The whole life cycle, Simulation.

1. Introduction

The BIM (Building Information Modeling) is based on three - dimensional digital technology and integrates the ancient buildings information models of various related information for developing ancient buildings projects. At the same time, it is a digital technology used in design, construction and management. [3-4]. In recent years, BIM technology has become an effective tool for historical building modeling and building information integration because of its visualization, coordination and simulation. The use of BIM technology in the protection of historical buildings has a very important meaning [7-8], and the application of BIM technology in the protection of the ancient buildings is still in the initial stage in China. It is of great significance for the protection and maintenance of ancient buildings in China to discuss the previous research results. [9-10]

Based on the theory of task scheduling in nonlinear environment, this paper studies how to achieve effective subcontracting and rational scheduling for ancient architectural tasks, so as to achieve the simulation of the whole life cycle problem

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of ancient buildings. According to the whole life cycle task of the ancient building project, the target task is determined, and the model is constructed on the basis of the model. Through the formulation of the scheme, the ancient building targets can be achieved in the shortest time. Therefore, the problem is essentially a NP complete problem, and this paper proposes a fusion of BIM technology life cycle simulation algorithm to simulate the implementation schedule subcontracting and scheduling.

2. Directed acyclic graph model and BIM Technology

2.1. The ancient building life cycle plan DAG model

In this paper, from the nonlinear dynamic database and the ancient building life cycle plan related data information from everywhere, the ancient building task becomes the basic unit of the schedule plan. And there are constraints between these tasks, and the corresponding DAG model contains two basic factors, the node and the edge,which can be shown in $\mathrm{DAG} = (\mathrm{T}, \mathrm{E})$. $T = \left(t_1, t_2, \cdots, t_{|T|}\right)$ represents the task node, mainly with the starting, terminating and other node types. In that DAG model , the constraint relationship between the nodes, or the order that the task should follow in the execution is expressed by the edge, which can be shown in $E = \left\{(e_{s,e})_i \,| i = 1, 2, 3, \cdots, |E| \right\}$. And $(e_{s,e})_i$is the edges of the two nodes about ts and te, which are referred to. The specific example figure of DAGmodel is shown in figure 1 below:

DAG

2.2. BIM Technology

The BIM technology of the life cycle plan of ancient buildings is used to analyze the related resource group data in a manual way. As shown in Table 1, it reflects the time consumption of the task node of DAG model corresponding to the life cycle plan of ancient architecture and the allocation of different resource groups. The BIM technical model can be reflected by table 1. The ordinate $t_i \in \left(t_1, t_2, \cdots, t_{|T|}\right)$ corresponds to the ancient building node of Figure 1. And the transverse coordinates $r_i \in R = \{r_i \,| i = 1, 2, 3, \cdots, |R|\}$ then corresponding to the resource group. $\mathrm{EcCost}_{r_j}(t_i)$ represents elements in the system with coordinates (t_i, r_j), it represents a resource group r_j assign to task node $t_i$and the time it takes to execute a task. If ther_j=0, when one of the resource groups is used in task execution, the resource group can be reallocated only when the task has ended. $\mathrm{AveW}(t_i)$ represents the node $t_i$and the average time when executing. It can be calculated by the next Formula:

$$AveW\left(t_i\right) = \sum_{k=1}^{|R|} \left(EcCost_{r_k}\left(t_i\right) / \left|R\right|\right) \tag{1}$$

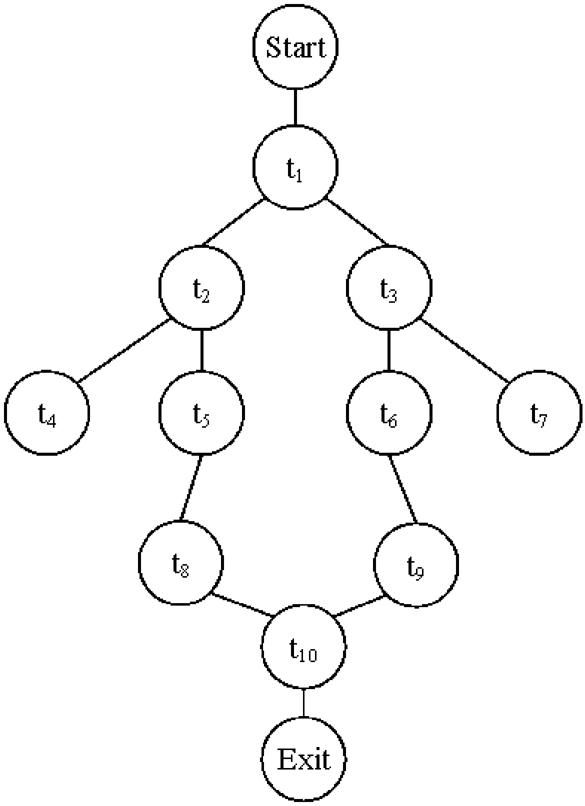

Fig. 1. DAGModel

Table 1. BIM Technology Model (Unit: 10 days)

Ancient Architectural Task	r1	r2	r3	......
t1	8	9	10	
t2	12	15	19	
t3	13	16	19	
t4	11	9	13	
t5	6	8	7	
t6	9	7	6	
t7	7	9	8	
t8	16	14	12	
t9	12	10	7	
t10	12	14	16	

since the nonlinear degree can be quantified and analyzed in a variety of ways for a non - linear model. In this article, select time redundancy(time − redundancy ratio, TRR)to carry out the quantitative analysis.

2.3. Mathematical Modeling of Life cycle scheduling in Ancient buildings

If contains T task nodes in DAGmodel and the group of resources contained in the BIM technology is "R", so $(t_1, t_2, \cdots, t_{|T|})$ represents a task scheduling sequence and s=$(r_1, r_2, \cdots, r_{|T|})$ represents a resource group allocation sequence solution for all tasks. The resource groups allocated by each element are one-to-one in $(t_1, t_2, \cdots, t_{|T|})$. If the task node t_i has the highest level scheduling, then possible formula (2) represents a resource group corresponding to $r_j$with the earliest start time. Tavail(r_j) represents the resource group r_j, which is responsible for the task t_i and the time required to execute. Tready(t_i) represents the time it takes to be ready of t_i, moreover, the calculation of time can be realized by the way of formula (3) and formula (4), exec(r_j) refers to a collection of all the tasks for which they are responsible about r_j, TAFTime(t_k) represents the amount of time spent executing about t_k,pred(t_i) represents all the precursor nodes of t_i. If you assign it to a resource group tor_j, if $t_i$is handled by non-preemptive means, then the formula (5) shows the earliest time of completion aboutt_i,then it can be shown inEcCost$_{r_j}(t_i)$. If the nodet_i is complete, then give a value ofTAFTime(t_i) toTEFTime(t_i, r_j), so the time required to complete the life cycle plan at this time (makespan) is t$_{Exit}$completion time, it can be seen in formula (6).

$$T_{ESTime}(t_i, r_j) = \max\{T_{avail}(r_j), T_{ready}(t_i)\} \tag{2}$$

$T_{avail}(rj) = max_{tk \in exec(rj)}\{T_{AFTime(tk)}\}$; If $t_i$belongs to the initial node or a terminating node, then it is:

$$T_{avail}(r_j) = 0 \tag{3}$$

Tready(ti) = maxtk∈ pred(ti){TAFTime(tk)}??If tibelongs to the starting node, it is:

$$T_{ready}(t_i, r_j) = 0 \tag{4}$$

$$T_{EFTime}(t_i, r_j) = T_{ESTime}(t_i, r_j) + EcCost_{r_j}(t_i) \tag{5}$$

$$makespan = \max_{t_i \in T}\{T_{AFTime}(t_i)\} = T_{AFTime}(t_{Exit}) \tag{6}$$

3. The ancient building life cycle algorithm

3.1. Calculation of full life cycle

Full life cycle refers to AveWis the biggest in DAGmodel??(the path and node about the sum of t_i. The full life cycle is not single but a sequence exists .The primary calculation in this phase is the full life cycle , the first is requiring a full life - cycle sequence to be constructed ,is $CP = \left(CP_1, CP_2, \cdots, CP_{|CP|}\right)$. The calculation can be carried out by the following formula :

Algorithm 1:GenCP(DAG, R)(whole life cycle iterative calculation)

1 i = 1;

2 While DAG exists task nodesdo

3 Calculate the full life cycle CPiin DAG

4 Completely removed the task notes about CPi and the corresponding edges in DAG, and get a newDAG.

5i = i + 1;

6End while

7return$CP = \left(CP_1, CP_2, \cdots, CP_{|CP|}\right)$

3.2. Calculate the full life cycle of dynamic constraints

The dynamic constraint full life cycle consists of a task node , and is a sequence with a topological structure . In this sequence, the whole life cycle of dynamic constraints is based on the foregoing calculation path of $CP = \left(CP_1, CP_2, \cdots, CP_{|CP|}\right)$, and the structure of the task node is extracted from it by a kind of wheeling method. The settlement is mainly to calculate the whole life cycle of this dynamic constraint. So corresponding sequences can be constructed: $CCP = \left(CCP_1, CCP_2, \cdots, CCP_{|CCP|}\right)$. The calculation can be carried out by the following steps:

Algorithm 2:GenCCP(CP)(the calculation of dynamic constraint full life cycle iterative)

1 j = 1;

2for i = 1 to|CP|

3 While CP_i exists ready node $t_k$do;

4 Put t_k into the sequence of CCP_j;

5end while

6j = j + 1;

7i = i% |CP|;

8end for

$$9\text{return}CCP = \left(CCP_1, CCP_2, \cdots, CCP_{|CCP|}\right);$$

3.3. Resource group allocation phase

Mentioned in this paper, FFCSA algorithm achieves the reorder about all CCP_i based on the head node's price of CCP_i downward – ranking(Rankt). Thus, it also get the corresponding Scheduling sequence about $RCCP = \left(RCCP_1, RCCP_2, \cdots, RCCP_{|RCCP|}\right)$. As follows the formula(7)and the formula (8) definesRankt. When the sort work according to the order of the scheduling sequence is complete and allocate the earliest and least completed resource groups of eachCCP_i determined by greed, so the corresponding resource group allocation sequence solution can be obtained .s

$$Rankt\left(t_i\right) = \max_{t_j \in pred(t_i)} \left\{AveW\left(t_i\right) + Rankt\left(t_j\right)\right\} \tag{7}$$

$$Rankt\left(t_{Start}\right) = 0 \tag{8}$$

The neighborhood structure improved by this method is better and more reasonable , which is also the innovation of the algorithm in this paper.

Algorithm 3:GenNH(s)(neighborhood structure generation method)

1 Define the corresponding load task of each r_i in s;

2 Determine the resource group with the maximum task load rmax from s;

3 Select one nj at random in the tasks undertaken of rmax;

4 Determine the resource group with the smallest task load rmin;

5 Allocate njto rmin, obtain a new distribution scheme s';

$$6 \text{ returns}';$$

4. Model Experiment

Using the software system designed and developed, the whole life cycle of ancient buildings is simulated and analyzed. The actual data of an A - old building in a city is used in this article. In order to verify the effectiveness of the algorithm, an application simulation experiment is carried out. And in order to analyze the relative advantages of the algorithm and its robustness, a comparison experiment is carried out.

4.1. Brief Introduction to Ancient Architecture

Taking the A ancient buildings in the city as the research object, and the life cycle of A ancient architecture is simulated by BIM technology. The simulation results are shown in Figure 2. In the space layout of A ancient building, it is necessary to carry out the initial planning on the east and west side symmetrically with considering the limitation of many factors in reality. Therefore, when using BIM technology to simulate the ancient building, it is necessary to consider the progress plan on the east and west side of the ancient building,and the other contents in the overall plan.

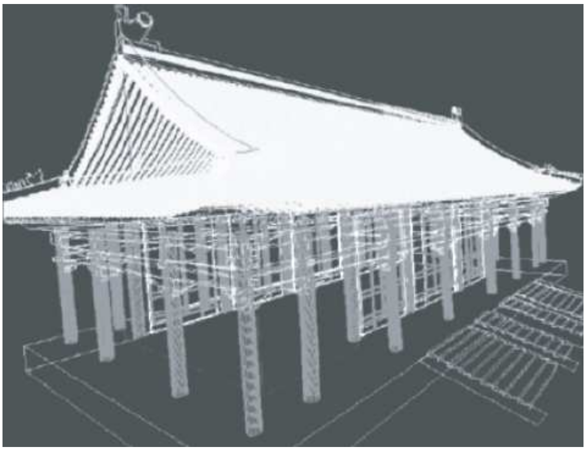

Fig. 2. A Historic Building

4.2. experimental parameters

(1)makespan: The ancient building life cycle plan overall completion time is the experimental results of the evaluation standard;

(2)Number of Resource Groups ($|R|$): refers to the number of resource groups that can be utilized in the construction of the project (In the simulation experiment, the ancient construction team was determined, which was actually involved in the subcontracting of the project.);

(3)Temporal redundancy (TRR): In practice, time redundancy is determined by combining the task execution capabilities of resource groups. In the simulation experiment, the time redundancy is quantitatively analyzed by time redundancy(TRR). TRRis set the percentage ahead of time according to the actual execution ability of the resource group. This indicator ensures that resource groups when perform their taskst_i , so the time range required is [(PFTimeti-PSTimeti)$\times(1 -$ TRR1),(PFTimeti-PSTimeti)$\times(1 -$ TRR2)]??(TRR2$<$ TRR1), TRR2TRR1both of them represent the lower and upper limit of time redundancy respectively. PFTimeti??PSTimeti is represents the note t_i's the start time and the end time in the original life cycle plan. Therefore, this can show the necessary time about the resource group r_j carry out the task ti in the formula (**??**). Thus, the interval can reflect the task execution ability of the resource group, and the nonlinear degree of the whole resource group model can be analyzed in this way. Furthermore, the maximum time savings are identified when the resource group is adequate. The time saved for the entire ancient building can be simulated through the planned simulation, which is realized in this way .

$$EcCost_{r_j}(t_i) = (PFTime_{ri} - PSTime_{ri}) \times (1 - rnd); \quad rnd \in [TRR_2, TRR_1] \tag{9}$$

The above parameters can be used to verify the simulation effect of the algorithm, and it can also be applied to the contrast experiment. By using the related parameters can be adjusted to achieve the analysis of the robustness of the algorithm, and further confirmed the advantage of the algorithm.

4.3. Application Simulation Experiment and Analysis

This section is mainly on the east side progress plan of A ancient buildings, the progress plan of the west side and the overall progress plan (part), a total of 122 tasks were simulated and analyzed through experiments. As shown in table 2, it represents the specific setting of the parameters. The interval of TRR is $[0, 5\%]$, represents the degree of nonlinearity is $0 \sim 5\%$ that the system has. That is, through the planning of ancient architecture as a whole can be saved in the range of time between.$0 \sim 5\%$.

Table 2. Simulation experiment parameter value setting

Parameter	East Side Schedule Parameter Value	West Side Progress Plan Parameter Value	Overall Progress Plan (part) Parameter Value
Number of Resource Groups	3	4	5
TRR Interval	$[0, 5\%]$	$[0, 5\%]$	$[0, 5\%]$
Task Number	17	54	51

The specific experimental results are shown in Table 3 and Fig 3. By analyzing the experimental data, it can be concluded that using MONDSalgorithm is able to simulate the original plan of the life cycle of the ancient buildings. For example, the eastern side of the progress of the ancient building time reduced by 45 days, the reduction range is 4.48; after simulation, the progress on the west side was reduced by 59 days and the reduction range was 3.68 compared with the original plan; while the overall progress plan (part) of the ancient buildings took 69 days to shorten by 4.31%. As a result, the time spent on the whole ancient building was reduced by 173 days, with a reduction of 4.13% days. Compared with the old building plan, it can save thirty-five million six hundred and forty-one thousand and six hundred yuan.

Table 3. Simulated experimental results (Unit : 10 days)

Ancient Architecture Life Cycle Plan	Planned Completion Time	The Required Time with FFCSA Simulation	The Saved Time by FFCSA	The Percentage of Saved Time%
Life Cycle Planning of Ancient Buildings on the Eastern Side	107	102.2	4.8	4.48
Life Cycle Planning of Ancient Buildings on the West Side	133	128.1	4.9	3.68
Integral Ancient Building Life Cycle Plan (part)	179	171.3	7.7	4.31

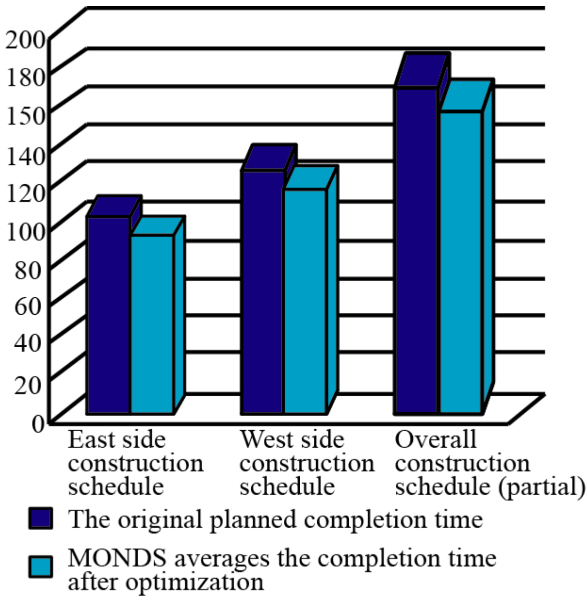

Fig. 3. Simulated Experimental Results Histogram

4.4. Fixed - time redundancy interval experiment

Table 4 represents parameter setting for the fixed - time redundancy interval experiment.

Table 4. Parameter setting of Interval Experiment with Fixed Time Redundancy

Parameter	East Side Schedule Parameter Value	West Side Progress Plan Parameter Value	Overall Progress Plan (part) Parameter Value
$\|R\|$	$\{2, 4, 8\}$	$\{2, 4, 8\}$	$\{2, 4, 816\}$
TRRInterval	$[0, 5\%]$	$[0, 5\%]$	$[0, 5\%]$
Task Number	17	54	51

In this experiment, the number of available resource groups is set to show incremental changes with 2x increasing, and also set the interval ofTRRis $[0, 5\%]$, which is shown in Table 4and Table 5. This also use the formula nine to identify $\mathrm{EcCost}_{r_j}(t_i)$ in task node which belongs to resource group in a random manner. The specific experimental results are shown in Table 5. If the resource group is not enough, the results obtained by the simulation experiment show that the required time is beyond the predetermined time, which can be obtained by the analysis of the experimental results, and this is also consistent with facts. As the number of resource groups is increasing , the time required to pass the simulation is gradually reduced. That is to say, the original ancient building plan can be simulated with FFCSA algorithm in the case of a growing resource group. However, CEFTis unable to schedule simulation??for the sorting of virtual nodes is relatively difficult in DAGmodel. But in this paper, FFCSA can solve this problem effectively. Therefore, it can be verified that the proposed method in the article has good performance. And the degree of simulation has also been greatly improved compared with the MHEFTalgorithm. For the introduction of CCP, the overall situation is more prominent of DAGgraph structure in FFCSA algorithm. And also can use theVNSmethod to achieve further simulation. Combined with the above analysis, it can be concluded that FFCSA algorithm has a comparative advantage in this article in the case of this incremental change in the resource group.

Table 5. Experimental results of time redundancy (Unit : 10 days)

The schedule of Eastern Side, *TRR* Interval=[0,5%]						
$\|R\|$	Planned Completion Time	Completion Time with MHEFT Simulation	the Percentage of Saved Time with MHEFT /%	Completion Time with CEFT Simulation	Completion Time with FFCSA Simulation	the Percentage of Saved Time with FFCSA/%
2	106	114.2	−7.74	156.1	113.7	−7.26
4	106	101.9	3.87	105.2	101.2	4.53
8	106	101.7	4.06	104.9	101.1	4.62
The Schedule of Western Side, *TRR* Interval=[0,5%]						
$\|R\|$	Planned Completion Time	Completion Time with MHEFT Simulation	the Percentage of Saved Time with MHEFT /%	Completion Time with CEFT Simulation	Completion Time with FFCSA Simulation	the Percentage of Saved Time with FFCSA/%
2	132	227.2	-72.12	370.1	225.9	-71.13
4	132	127.2	3.63	229.9	125.8	4.69
8	132	126.2	4.39	103.3	125.4	4.91

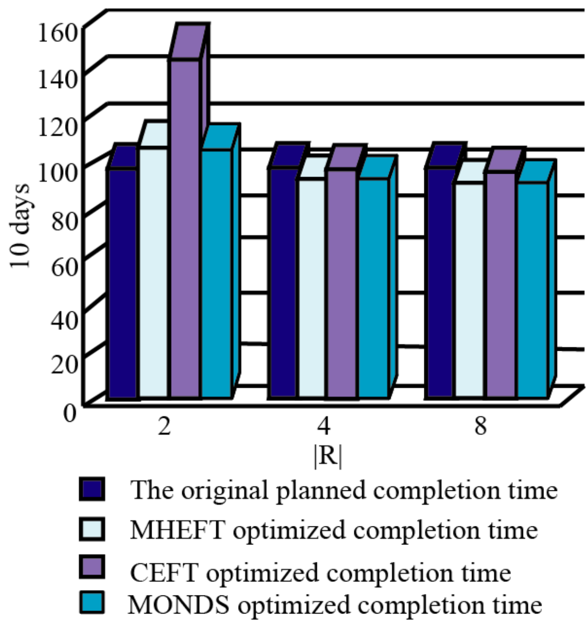

Fig. 4. On the eastern side of the ancient building life cycle time redundancy results

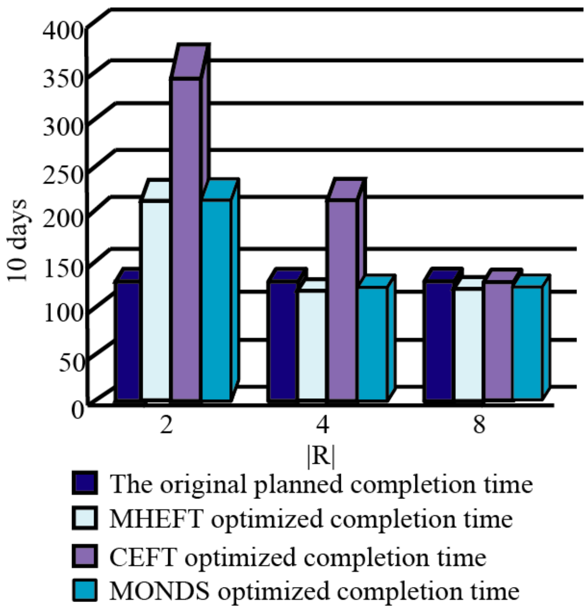

Fig. 5. On the western side of the ancient building life cycle time redundancy results

5. Conclusion

Based on the theory of task scheduling in nonlinear environment, this paper simulates subcontracting and scheduling in the whole life cycle of ancient buildings. In practice, a nonlinear problem of resource group is common, and this article also put forward the FFCSA algorithm with ancient architecture life cycle plan in DAG model and BIM technology . FFCSA algorithm reorders the dynamic constraint life cycle plan and the simulation of neighborhood structure is realized with VNS method??so the problem of target simulation is solved. By using the algorithm, the simulation scheme can be developed , and the minimum time required for the completion of the ancient construction life cycle plan can be obtained .The application software corresponding to the above model and algorithm is also designed in this paper. And it has proved the validation of the FFCSA algorithm performance in this article with the relative information about A ancient architecture in a city, and the proposed algorithm in this article has an advantage over CEFT and MHEFTwhen the data conditions are different.

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