Adaptive Adjustment Method for Construction Progress of Fabricated Buildings Based on Internet of Things

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Abstract. Traditional assembly-type construction progress projects have shortcomings such as long construction period, poor environmental benefits and high building energy consumption. In view of these problems, this paper proposes an adaptive adjustment method of prefabricated building construction schedule based on Internet of things. Utilize the advantages of the Internet of Things, collect information on the construction progress, and then effectively scan and bind according to the construction progress information. Then build the progress management data information model of the prefabricated building project, calculate the minimum value of the maintenance cost load in the construction progress, and realize the adaptive adjustment target of the project schedule. The results show that the adaptive adjustment method of the construction progress of the fabricated building based on the Internet of Things is superior to the traditional method in engineering error rate and construction safety, which greatly reduces the construction period and is more effective in use.

Keywords: Internet of Things · Prefabricated building · Construction progress · Self-adaption · Method of adjustment

1 Introduction

As an important pillar industry of China's economy, the construction industry is crucial for the development of its digitalization and integration. In recent years, as an important breakthrough for the transformation and upgrading of the construction industry, the prefabricated building is the key to realizing the continuous innovation and development of the construction industry and leading development [1]. Internet of Things technology is a hotspot technology used in the construction industry. It mainly uses RFID technology and traditional wireless networks, and combines BIM technology to build an information system. In foreign countries, SONG JC and others have realized the automatic tracking and real-time information acquisition of building materials by combining RFID and GIS technology to locate building materials. In China, Chang Chunguang and others applied RFID technology and BIM technology to the assembly building, and studied the application process based on these two technical systems [2]. However, the short data transmission distance, the anti-interference of the wireless

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communication network and the high network transmission cost have become obstacles to the application of the Internet of Things technology. In the past two years, a new type of ultra-long thermal distance and low-power data transmission technology based on 1 GHz and below, which is called LoRa technology, was released by Semtech. As a kind of low-power wide-area Internet of Things, it has revolutionized the Internet of Things technology. By using spread spectrum technology and special LoRa modulation, it has the advantages of long transmission distance, strong penetrating power, low cost and low power consumption at low transmission rate. At present, LoRa technology is mainly used in smart parking lots, remote wireless meter reading, smart agriculture, intelligent street lamps, etc. The construction industry will become a new application field of this technology. The solution in this paper aims to fill the application gap of LoRa wireless communication technology in prefabricated buildings, and make breakthroughs in the digitalization, networking and intelligence of the construction industry [3].

2 Adaptive Adjustment Method for Prefabricated Construction Progress

In order to obtain the actual progress of the construction site, on-site personnel are required to collect information, and then complete the data collection and then compare with the planned progress. This method can't check the construction progress anytime and anywhere, can't adjust the network plan in time, and can't control the construction speed in time, which is not conducive to refined management. The integration of RFID and BIM technology enables real-time control of the progress management of fabricated buildings [4].

2.1 Construction Progress Information Collection

First of all, the BIM technology is used to model the prefabricated building (the current stage is overturned), and each major is synthesized, collided and deepened. Secondly, after completing the deepening design, each component is coded on the model, and the coding is simple and easy to understand. The relevant information of the component is hooked up, and the location information and planning time information need to be written in advance [5]. Then, the components coded by BIM technology are automatically plotted, and the drawings are handed to the PC component processing factory for processing. The encoding, naming and planning information in the model tag is processed and stored on the RFID chip, which is embedded in the prefabricated components [6]. Once again, after completing the component processing, the components are transported according to the planned time, and the actual factory time, the actual entry time, the actual delivery time, the actual admission time, and the actual lifting time are recorded. Finally, the hoisting equipment such as tower crane is used for assembling. If the accuracy is qualified, the installation time is automatically read and recorded. If the installation accuracy does not meet the requirements, a warning is issued. The whole process of assembly design, production, transportation and hoisting is shown in Fig. 1:

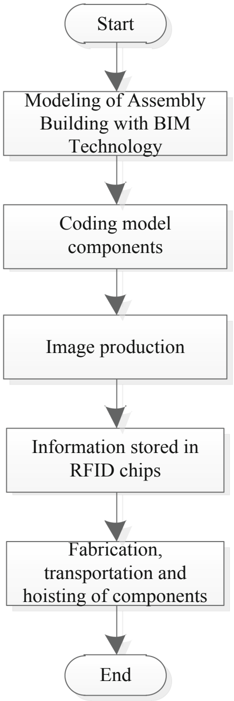

Fig. 1. The whole process of assembly component design, production, transportation and hoisting

The planning time of the different stage components can be linked to the component in advance, can be implemented in the modeling software, or can be implemented in BIM 5D or other progress simulation software. The actual time of the component can be imported into Revit through the secondary development software through the information of the reader, thereby realizing the information collection of the schedule. This “BIM + RFID” model satisfies the entire process of information management of component production and transportation, and can be reverse traced. It can not only ascertain the relevant time information of the component, but also track its responsible person and operator to facilitate the quality control of the component.

2.2 Effective Scanning and Binding Based on Construction Progress Information

Active tag (IoT transport module) saves the attribute information of the component in the module’s memory before embedding. After the component is embedded in the active tag, the constructor can scan the RFID tag of the component through the RFID reader and upload the information to the cloud server. At the same time, the active tag is positioned by the GPS to locate the component, and the saved information in the tag is transmitted to the cloud server through the transmission module. The information of the passive tag and the active tag is then matched and bound in the cloud server. Through this matching method, the real-time information of the component can be saved to the cloud server through the transmission module of the active tag. And through the cloud server to update to the construction personnel's terminal equipment in real time, so as to record the installation location, arrival date, installation date and other information of the component in real time [7]. After the information is complete, the label is embedded on the prefabricated component. Since the reader installed at the construction site can read and recognize the component information held in the electronic tag without contact, the purpose of automatically identifying the component information is achieved. In this way, the components can be written to the actual time by hand scanner from production, storage to delivery [8]. On-site fixed readers can read a large number of label information, and have the characteristics of oil resistance, fast reading and writing speed, reliable information and timely. The collected information is connected to the computer through the reader, and the tag information read is the actual progress information of the component. This information is transmitted to the computer, and the simulation of the actual progress information is compared with the simulation of the planned progress to find out the cause of the impact [9, 10]. Using RFID technology to collect the actual production time of the component, the actual storage time, the actual delivery time, the actual admission time, the actual transportation time and the actual lifting time, the process is shown in Fig. 2. Make sure that the state of the component is visible at all times to prepare for subsequent call information.

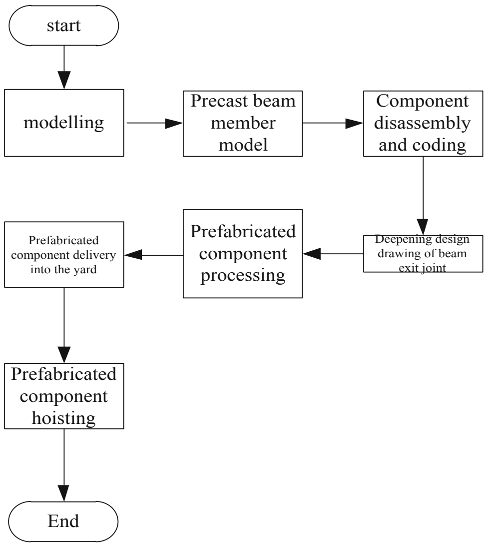

Fig. 2. BIM, RFID technology application

2.3 Constructing a Schedule Management Data Information Model for a Prefabricated Building Project

After selecting the best construction plan through the comparison of the plan, it is necessary to integrate the relevant information of the construction plan. And enter the information into the BIM model to establish a building model or planning network entity that matches the actual engineering conditions. For hoisting construction, the application of BIM technology is mainly reflected in the establishment of a construction model to simulate the implementation effect of the on-site construction plan. And according to the components selected for the construction of the project, the installation location and installation sequence of the components are clearly defined to facilitate construction guidance and scheduling. It should be noted that quality and performance inspections are required before the components enter the site, and the explanatory materials and quality certificates issued by the manufacturer are checked. After inspection, they can be put into use. At the same time, the command and dispatch management personnel can work through the on-site handheld equipment. The construction hoisting model is directly displayed on the handset. Field personnel can use handheld devices to scan the components and analyze the structure and related information of the components. Compare with the construction design plan, conduct in-depth research on the causes of the differences, improve the on-site construction work, and ensure the quality of component installation. Intuitive understanding, so that the construction team has an understanding of the building information, effectively avoiding the occurrence of installation errors, so that work efficiency and installation quality are improved. In addition, through mobile devices, such as tablets, mobile phones, etc. combined with RFID and cloud technology, the instructors can guide the construction conditions in different places, enabling field personnel to locate components smoothly. And hoisting this, it is also possible to query the parameters of the component parameters and the quality indication in real time. And uploading the completion data to the project database, you can trace the query about the construction quality and apply the BIM technology to the construction safety management. Firstly, the organization decision-making basis and construction plan can be provided to the safety management work. In addition, the overall construction process can be remotely monitored at the same time of construction, which plays a very good role in preventing safety hazards. From the application case of BIM technology, it can be analyzed that the simulation of BIM technology can identify some security risks. Each process of construction can be presented in the simulation. Through the model, not only can the visual characteristics of the construction site be intuitively understood, but the technical personnel can also inspect the construction plan in advance. In the simulation process, the emergency plan for the dangerous situation can be similar to the traditional engineering project. When constructing the construction project schedule, each key construction node should be considered. In addition to this, there is an important condition, that is, the order in which the prefabricated components are hoisted. Under normal circumstances, these tasks are done manually, but the manual error is large, and the plan to complete the entire lifting process is difficult to ensure accuracy. The introduction of BIM technology just makes up for this shortcoming and can make the lifting process efficient and quick. Then import the file into Navisworks and associate with the building BIM model, so that you can accurately organize the time and amount of engineering required for each project. Therefore, the specific construction plan is determined, and after all the information is collected, the 5D simulation work is carried out. At this point, the construction progress can be more clearly reflected, and the schedule can be more comprehensively organized to apply BIM technology to the construction schedule management to ensure that the process can be carried out in an orderly manner [11, 12]. At the same time, the overall view of managers should be strong. The important nodes and schedules should be compared to make the time and space allocation reasonable and make the best use of them. The building information model is the core, and the delay of the construction period can be avoided as much as possible. In terms of schedule management, the BIM model can be used as a basis for decision-making. While promoting construction, it is inevitable that some unforeseen unexpected situations will occur, resulting in disruption of the construction schedule. At this point, the construction schedule can be adjusted immediately according to the BIM model to avoid the construction schedule not being able to progress smoothly due to the untimely change, which leads to more errors.

2.4 Maintenance Cost Load Calculation in Construction Schedule

BIM-based 5D dynamic construction cost control is based on the 3D model, adding time and cost to form a 5D building information model. Through the virtual construction to see whether the material stacking, project progress, and capital input are reasonable, timely discover the problems existing in the actual construction process. Optimize the construction period, resource allocation, adjust resources and capital investment in real time, optimize the construction period and cost targets, and form an optimal building model to guide the next construction. Suppose a production line has II specifications, each specification produces $A = \{A_1, A_2, A_3, \cdots A_n\}$, s is the total number of products produced, and j represents a possible production sequence.

$$J = \{J_1, J_2, J_3, \cdots J_n\}, s = \sum_{i=1}^{n} A_i \text{ 俥} \tag{1}$$

There are a total of m stations in the production line, and the processing time of each product in each station is matrix p. p_{ik} represents the processing time of the $i = (1, 2, 3 \ldots \ldots .n)$-th specification at the k-th station. For production plan J, the completion time of product J_j at station k can be expressed as $C(J_j, k)$, and the maximum completion time for the entire production plan is $C(J_s, m)$. Therefore, the most critical issue of the dynamic cost control problem is to solve the minimum $C(J_s, m)$, i.e., solve $\min C(J_s, m)$.

The same work station in the manufacturing industry can only process one product at a time, and the dynamic cost control in the assembly construction has its particularity. It mainly shows that multiple products can be cured at the same time in the dynamic cost control process, so the maintenance process is parallel. Secondly, considering that the product curing time is long, it is generally completed in non-working hours, and the start time of the next process after curing cannot be in non-working time, so it is postponed to the next working day. In addition, a series of processes of dynamic cost control cannot be interrupted and must be carried out continuously. The overtime of the process is OT. If the pouring operation is still not completed within the overtime hours, it is postponed until the next day, and other processes such as mold installation can be interrupted, so the overtime is $OT = 0$. The working time per day is TW, generally $TW = 8$ h, and non-working time is $TN = 24 - TW$. The completion time of each cost control task is as follows:

$$T = Max\begin{cases} C, (j_{j-1}, k), C\left(J_j, k-1\right) + P_{jk} \\ Int(T/24) \end{cases} \tag{2}$$

$$C(J_j, k) = \begin{bmatrix} T \cdots if(T \leq 24D + TW + OT) \\ \vdots \\ 24(D+1) + P_{jk}, if(T \geq 24D + TW + OT) \end{bmatrix} \tag{3}$$

For concrete curing, since it can be processed in parallel,

$$T = C(J_j, k-1) + P_{jk} \tag{4}$$

The objective function is $f(x) = \min\ C(J_s, m)$, S is the total production task or order, and m is the number of 5D dynamic cost control or the number of stations in the assembly construction progress.

2.5 Realize the Progress Adjustment Target of Engineering Progress

Progress management is one of the three goals of project management. Using information technology to collect the actual progress of the fabricated components, so as to effectively arrange the construction tasks, so that the construction progress deviation is within the range. The use of RFID technology to achieve automated collection of actual progress saves a lot of manpower. Once the products of the building components are produced, they are irreversible. Once the error exceeds the controllable range, the components will be unusable, so the assembled buildings are highly demanded in the engineering design stage. Compared with the traditional construction method, the adaptive adjustment method of the assembly building schedule is more energy-saving and environmentally friendly, and is less affected by environmental factors. It can speed up the construction progress, make the project put into use as soon as possible, and exert production value. Realize no green formwork, no external scaffolding, no on-site masonry, no plastering green construction. Adopt "less specifications, multiple combinations" design principles to reduce construction costs and shorten construction period; use green technology to save later operating costs.

3 Simulation Experiment Demonstration and Analysis

In order to ensure the effectiveness of the adaptive adjustment method of the IoT-based fabricated building construction schedule designed in this paper, the simulation experiment demonstration analysis is carried out. Prefabricated component production tasks are generated by the production planning task entity and then processed by subsequent workstations one by one. When the prefabricated production components are processed on the workstation 9, the components are lifted, transported and stored in the component yard. The operational time of an activity is determined by its corresponding distribution function entity. In traditional prefabricated production, production is driven by production plans. In the simulation, queue entities are used to represent buffers between workstations. When a workstation is working, tasks are queued and waiting for a certain amount of time. Each queue entity can store multiple tasks. The linked files can be seen from the management project management link. The layout of the construction site is completed according to the imported CAD drawings. The optimized 3D model of the construction site layout is shown in Fig. 3.

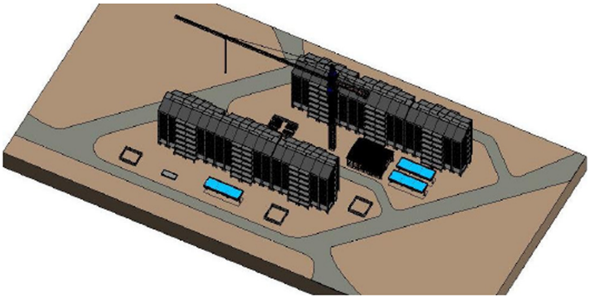

Fig. 3. Construction layout model

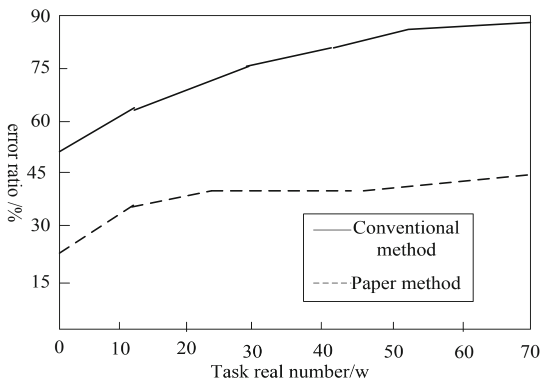

Fig. 4. Experimental comparison chart

In the process of data collection, due to unclear time definition, irregular statistical process and special conditions on site, it is easy to cause some data to be too large and too small. Therefore, first of all, the most basic data processing, the removal of abnormal data, and then the remaining data processing.

In order to ensure the effectiveness of the experiment, the traditional method and the adaptive adjustment method based on the IoT-based assembly building construction progress were compared, and the construction error rate of the two methods was statistically analyzed. The experimental results are shown in Fig. 4.

According to the analysis of Fig. 4, the engineering error rate of the adaptive adjustment method of the prefabricated construction progress based on the Internet of Things is far lower than that of the traditional method. Therefore, it can be concluded that the adaptive adjustment method of the prefabricated construction progress of the Internet of Things designed in this paper largely avoids the situation of on-site rework, waiting for work, secondary transportation, etc. He has obviously improved the quality of the project and also ensured the safety of the construction. Through the combination of the prefabricated component management system and the Internet of Things technology, the information management technology is used to optimize the management of the prefabricated components, which saves the process of mutual data exchange among various professions, and the communication efficiency is improved, and the construction period is significantly shortened.

In the process of project management, the integrated management of cost/schedule can be realized by adjusting the proportion of prefabrication (Fig. 5).

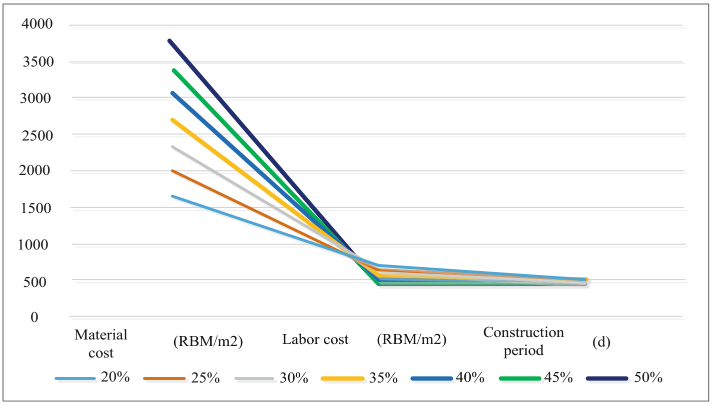

Fig. 5. Change trend of cost and schedule under different prefabrication proportion

As can be seen from the above figure, when summarizing the cost progress of each month, the prefabrication proportion can be adjusted appropriately according to the specific situation of that month. Strictly control the cost of each stage of the project, fully consider the possibility and trend of price changes in each stage of the project, and make timely adjustment measures according to the specific implementation situation, such as how to adjust the project schedule in case of natural disasters.

4 Conclusion

This paper analyzes and experiments on the adaptive adjustment method of the construction progress of the prefabricated building based on the Internet of Things. Based on the advantages of the Internet of Things, the information acquisition is carried out, and the design of the design and the information carried are obtained. After that, according to the design of the deepened design and the information carried, the production planning is completed, the production plan optimization of the precast concrete components is completed, and the construction schedule planning process is accurately controlled. The experimental results show that the adaptive adjustment method of the construction progress of the prefabricated building based on the Internet of Things is very efficient. When it progresses in the construction of the prefabricated building, it significantly improves the quality of the project, shortens the construction period, and ensures the safety of construction. It is hoped that the research in this paper can provide theoretical basis and reference for the adaptive adjustment method of assembly construction progress in China.

References

1. Jianguo, X., Jia, Z.: Prediction simulation of parallel transmission path of Internet of Things data. Comput. Simul. **35**(1), 172–175+231 (2018)
2. Xiaodan, L.: Study on construction process planning and control of assembly building. Doctorate thesis of Dalian University of Technology (2018)
3. Yang, X.: Research on application of BIM Technology in construction stage of assembly building. Master thesis of Wuhan University of Engineering (2017)
4. Liu, S., Li, Z., Zhang, Y., Cheng, X.: Introduction of key problems in long-distance learning and training. Mobile Netw. Appl. **24**(1), 1–4 (2018). https://doi.org/10.1007/s11036-018-1136-6
5. Bortolini, R., Formoso, C.T., Viana, D.D.: Site logistics planning and control for engineer-to-order prefabricated building systems using BIM 4D modeling. Autom. Constr. **98**, 248–264 (2019)
6. Jelena, N.: Building “with the systems” vs. building “in the system” of IMS open technology of prefabricated construction: challenges for new “infill” industry for massive housing retrofitting. Energies **11**(5), 1128 (2018)
7. Yuan, Z., Sun, C., Wang, Y.: Design for Manufacture and Assembly-oriented parametric design of prefabricated buildings. Autom. Constr. **88**, 13–22 (2018)
8. Dou, Y., Xue, X., Wang, Y., et al.: New media data-driven measurement for the development level of prefabricated construction in China. J. Clean. Prod. **241**, 118353 (2019)
9. Jrade, A., Jalaei, F.: Integrating building information modelling with sustainability to design building projects at the conceptual stage. Build. Simul. **6**(4), 429–444 (2013). https://doi.org/10.1007/s12273-013-0120-0
10. Zhao, L., Liu, Z., Mbachu, J.: Development of intelligent prefabs using IoT technology to improve the performance of prefabricated construction projects. Sensors **19**(19), 4131 (2019)
11. Fu, W., Liu, S., Srivastava, G.: Optimization of big data scheduling in social networks. Entropy **21**(9), 902 (2019)
12. Shuai, L., Weiling, B., Nianyin, Z., et al.: A fast fractal based compression for MRI images. IEEE Access **7**, 62412–62420 (2019)