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# Research on Management Mode of Project Construction Progress Based on 3D Modeling of UAV

Zhengyu ZHU[a,1], Wei ZHANG[b], Xuefeng LI[c] and Tianwen PENG[d]
[a]*State Grid Jingzhou Electric Power Supply Company, Jingzhou, 434000, China*
[b]*State Grid Gong'an Power Supply Company, Jingzhou, 434300, China*
[c]*State Grid Jingzhou Power Supply Service Command Center, Jingzhou, 434300, China*
[d]*Economic and Technological Research Institute of State Grid Jingzhou, Electric Power Supply Company, Jingzhou, 434300, China*

**Abstract.** In order to explore a time-saving, labor-saving and efficient and accurate construction monitoring method, the method of project construction progress monitoring based on UAV 3 d modeling is proposed. The coordinates of three-dimensional real scene model and BIM model are converted into the unified coordinate system, and import MicroStation and platform to realize the precise integration of three-dimensional real scene model and BIM model; then based on MicroStation platform, and a construction progress analysis plug-in is developed to realize the matching, segmentation and calculation of three-dimensional real scene model and BIM model, reflecting the actual construction progress with the ratio of completed component volume to the total volume of BIM component, so as to realize the automatic monitoring of project construction progress. The results show that the construction progress of the first to eighth span is higher than 90%; the concrete for the transverse connection of the ninth to fourteenth span girder is not poured, and the construction progress is less than 90%. The construction progress of the first seventh and ninth and tenth main girder on the right side of the bridge is above 97%; the construction progress of the first to seventh main girder on the right side is higher than 95%. Conclusion: This method solves the problem that it is easy to solve the real situation by relying on BIM model alone, effectively reduces the workload, improves the degree of monitoring automation, and avoids the error caused by artificial subjective matching and calculation.

**Keywords.** Highway, BIM, tilt photography, construction monitoring

## 1. Introduction

As the pillar of the national economy, the scale of China's construction industry has been expanding, but there is still the problem of backward organization mode of engineering construction. Accelerating the improvement of the project construction organization mode also has higher requirements for the progress, quality and cost of the construction projects. The construction schedule management of construction projects is distributed in every link of the project construction process, which is an important basis for the resource procurement and scheduling of the construction site. It is very important to

[1] Corresponding Author: Zhengyu ZHU, 16888523@qq.com.

whether the construction period can be completed on schedule, and also an important prerequisite for the completion of the project construction contract requirements [1]. Reasonable and efficient construction schedule control can not only help all participants to reduce the construction cost, but also realize the efficient allocation of construction resources. In China, although some enterprises make rapid progress in the actual construction process, within the prescribed period of time to complete the requirements of the contract, but in the process of implementation mainly by increasing the intensity of labor, materials, machinery and other resources to complete, rather than by improving the construction schedule management method to improve the management efficiency. With the increasing complexity of modern engineering projects, the management requirements of construction progress are also gradually improved. Traditional construction progress management, the common management mode mainly include the diagram, key lines, plan review, through the construction management personnel in the construction site patrol, to verify the progress of different construction activities and understand the current state of the project, to time limit for a project, resources, cost index of the actual completion compared with the implementation plan, to judge the construction progress and output construction progress report. After the progress deviation was found, the cause of the deviation was manually analyzed, and the deviation-based adjustment plan was issued [2]. Such construction progress management not only needs to collect information manually in the construction site, but also needs to collect information from construction drawings, budget information and various reports. There are obviously many problems such as low degree of automation, time-consuming and laborious, strong subjective judgment and decentralized management, which is difficult to meet the increasingly strict requirements of construction period. How to improve the efficiency of construction schedule management on the premise of ensuring the construction quality and construction safety is a problem worthy of research and challenge. In terms of improving the efficiency of construction schedule management, we mainly benefit from the intelligent construction technology [3]. BIM technology is widely used in engineering project management with its advantages of high 3 d visualization degree, strong information integration ability and easy multi-party collaboration. BIM 4D Is a visual model including the construction progress, which has a good advantage in simulating the construction process, visual progress optimization management. At present, in most of the engineering projects, the ideal model is built in advance before the construction to simulate and guide the subsequent project construction. BIM modeling in this way is difficult to realize intelligent real-time monitoring of construction progress, and it is difficult to control the actual construction situation [5–6].

This paper will mainly the drone tilt photography technology for three-dimensional real model and highway BIM model as the carrier of construction progress monitoring data, using the construction progress analysis based on the secondary development of MicroStation platform plug-in, through the boolean algorithm fast 3 d real model and highway BIM model matching, segmentation and calculation, get the construction progress report. The construction progress analysis plug-in obtains the actual construction progress of the project in K114 + 700 to K116 + 200 section of a highway project, and compares the actual construction progress with the planned construction progress, finds out the construction progress deviation, and corrects it in time, so as to realize the automatic monitoring of the highway construction progress.

## 2. Research Methods

### 2.1. Basic Principle of UAV Tilt Photography Technology

UAV tilt photography technology is a high and new technology developed in the field of international surveying and mapping in recent years. Different from the traditional orthophoto images taken at a single Angle, the technology is equipped with multiple sensors on the same flight platform, and collects data from vertical, left, right, front and back directions to quickly obtain the high-resolution texture information on the top and side of the measured object. In addition, through the principle of computer vision, the same name points in the tilted image are automatically matched and identified to generate the 3 D point cloud data, and then connect the point cloud data to build an irregular triangle network for texture mapping. Finally, the high-precision 3 D real scene model [7] is generated by combining the image POS point data and the ground control point data. Compared with traditional surveying and mapping methods, uav tilt photography technology has the advantages of high efficiency, large range and multiple data, and is widely used in many fields such as public security, planning and surveying and mapping.

### 2.2. Key Technologies of UAV Tilt Photography Technology

#### 2.2.1. Intensive Matching of Multiple Visual Images

The dense matching of multiple images mainly refers to the identification and extraction of the same feature points of the same features between multiple tilted images, so as to match the same features in multiple images. The image data obtained by uav tilt photography technology comes from a variety of perspectives, which has the characteristics of wide range, high resolution and rich texture information, which can greatly improve the fault tolerance of image matching.

Use the pyramid matching strategy to collect the size of the image resolution, establish the image data pyramid by ranking from top to bottom, and construct the Gaussian difference scale space under the processing of Gaussian convolution and continuous filtering. The following equation (1) (2):

$$D(x,y,\sigma) = (G(x,y,k\sigma) - G(x,y,\sigma)) \times I(x,y) = L(x,y,k\sigma) - L(x,y,\sigma) \quad (1)$$

$$G(x,y,\sigma) = \frac{1}{2\pi\sigma^2} e^{\left(\frac{x^2+y^2}{2\sigma^2}\right)} \quad (2)$$

$G(x,y,\sigma)$ — Gaussian convolution kernel;
$D(x,y,\sigma)$ — Gaussian difference scale space;
$I(x,y)$ — Image expression;
$k$ — The ratio of the two scale factors;
$\sigma$ — Gaussian convolution smoothing factor;
$L(x,y,k\sigma)$ — Scale space of the image in the plane space.

#### 2.2.2. 3D TIN Grid Construction

After completing the dense matching of multi-visual images, the image data is identified and extracted to generate ultra-high density three-dimensional point cloud data, and the point cloud is connected to form an irregular triangle network (Triangulated Irregular Network, TIN). TIN is a dense triangular network composed of three points, and its density increases with the increase of aerial photography. For areas with complex terrain, high density TIN can more accurately reflect the attribute information of relevant targets.

#### *2.2.3. Texture Mapping*

The traditional 3 D real scene modeling method is to establish the initial three-dimensional white mode by using the information data such as the survey area topographic map and the orthographic image, then collect the field photos, extract the texture information in the photos, and finally conduct the texture mapping of the three-dimensional white mode. This method is time-consuming, laborious and poor texture mapping, and is no longer widely used. The image data obtained by the UAV tilt photography technology comes from multiple angles, and the resolution is high, so the texture information of the ground object can be clearly seen through the tilt image. The instantaneous attitude of the shooting is obtained through the internal and external orientation elements of the image data, and then the surface of the 3 D model is connected and the 2 D tilted image data are connected based on the irregular triangular grid. Finally, the texture information is mapped on the 3-dimensional white mode, that is, the automatic texture mapping technology. Automatic texture mapping technology is convenient and fast, good fit, has been widely used.

### *2.3. Basic Principle of Construction Progress Monitoring*

The basic principle of construction progress monitoring is tilted photography technology for three-dimensional model and BIM technology for BIM model for data basis, the unified coordinate system of two different format model into the MicroStation platform, development of construction progress analysis plug-in, boolean algorithm to match two models, so as to obtain the construction progress.

Boolean algorithm is a logical deduction method of number notation, which can reproduce, merge and find the difference of multiple simple two-dimensional shapes and three-dimensional entities, and reorganize new three-dimensional entities. Suppose A and B respectively represent two entities, and, according to the derivation of computer graphics and computational geometry, the formula of the Boolean operation between the two entities is as follows (3):

$$\begin{cases} \mathrm{A} \cap \mathrm{B} = \mathrm{A\ inB} + \mathrm{Bin\ A} \\ \mathrm{A} \cup \mathrm{B} = \mathrm{A\ outB} + \mathrm{B\ out\ A} \\ \mathrm{A} - \mathrm{B} = \mathrm{A\ out\ B} + (\mathrm{Bin\ A})^{-1} \\ \mathrm{B} - \mathrm{A} = \mathrm{B\ out\ A} + (\mathrm{A\ in\ B})^{-1} \end{cases} \tag{3}$$

$A$ InB, $A$ outB — The surface of entity A is located both inside and outside of entity B;

$(A \text{ in } B)^{-1}$ — A set of the surface of A within entity B. Similarly, get the meaning of the remaining symbols.

Matching process of 3 D real scene model and BIM model: first, the envelope is generated with the BIM model as the minimum unit; then, the 3 D real scene model uses the 3 D real scene model boundary to complete the model matching; finally, based on the matching, the ratio of the resulting model and the minimum unit, and obtain the construction progress of the component.

## 3. Results Analysis

### *3.1. Road Engineering Progress Monitoring*

The highway construction progress monitoring method proposed in this study is used to monitor the construction progress of a highway project. According to the designed construction progress monitoring and management module, and the functions of the developed construction progress analysis plug-in is applied in the construction monitoring process, match, cut and calculate the three-dimensional real scene model and BIM model, and output the detailed report of the project construction progress [8–9].

The road engineering construction progress analysis takes 150 m as a section. The road construction section of the front pile number K114 + 700-K115 + 150 of the Jiwei Bridge is divided into three sections: (a) K114 + 700-K114 + 850, (b) K114 + 850-K115 + 000 and (c) K115 + 000-K115 + 150. (A) the construction progress of the left and right sides of the road in the section is higher than 90%, indicating that the construction is about to be completed; (b) the construction progress of the right side of the section is less than 80%; the construction of the right side of the 3 (c) section is about to complete, while the construction of the left side of the road is ongoing, and the construction progress is less than 60%.

The construction progress analysis plug-in can export the construction progress in the form of a table, and the construction progress of the pile number K115 + 830-K115 + 980 road is shown in Table 2. As can be seen from Table 1, the base construction progress of the left and right sides of the road is 96% and 98% respectively, indicating that the construction of the base part is about to be completed, and the construction of the surface layer and the central separation zone has not started.

**Table 1.** Road Construction Schedule.

| | **Build coding** | **Build type** | **Concrete volume ($m^3$)** | **completed amount ($m^3$)** | **rate of progress** |
|---|---|---|---|---|---|
| 1 | Face layer-right amplitude | Above the layer | 5251.535 | 0 | 0 |
| 2 | Face layer-left amplitude | Below the layer | 5278.467 | 0 | 0 |
| 3 | Base-right | grass-roots unit | 9451.903 | 9262.45 | 98% |
| 4 | Base-left | grass-roots unit | 9489.058 | 9111.44 | 96% |
| 5 | Bottom base-right | subbase course | 5255.5 | 157.860 | 93% |
| 6 | Bottom base-left | subbase course | 5277.462 | 369.392 | 7% |
| 7 | medial divider | dividing strip | 3614.365 | 0 | 0 |

According to the road construction progress obtained by the analysis, the construction of the pile number K115 + 830-K115 + 980 is the same as the construction plan, and the subbase of the pile number K115 + 000-K115 + 150 is not completed, and compared with the construction schedule, there is a significant delay in the construction progress [17].

### 3.2. Bridge Project Progress Monitoring

**Table 2.** Construction progress of the left main beam.

| | Component coding | Concrete volume ($m^3$) | Completed amount ($m^3$) | rate of progress/% |
|---|---|---|---|---|
| 1 | Face layer-right amplitude | 7.12 | 7.118 | 100 |
| 2 | Face layer-left amplitude | 7.15 | 7.007 | 98 |
| 3 | Base-right | 7.2 | 7.129 | 99 |
| 4 | Base-left | 7.118 | 6.976 | 98 |
| 5 | Bottom base-right | 1.216 | 7.144 | 99 |
| 6 | Bottom base-left | 7.189 | 7.043 | 98 |
| 7 | medial divider | 7.155 | 7.154 | 100 |

Classify the components of bridge engineering, and analyze the construction progress information of all kinds of components. Table 2 is the construction schedule of the left main beam. It can be seen from the table: the construction progress of the first to the eighth span is higher than 90%; the concrete for the transverse connection of the ninth to the fourteenth span main beam is not poured, and the construction progress is less than 90%. The construction progress of the first seventh and ninth and tenth girder on the right side of the bridge is above 97%; the construction progress of the first to seventh girder on the right side is higher than 95%.

### 3.3. Comparison of the Construction Progress

According to the information of the construction schedule, the BIM model simulated the construction, located the date, and obtained the planned schedule BIM model of the bridge project on March 22, 2022. Table 3 is the construction progress report of the bridge guardrail derived from the construction schedule analysis plug-in. Through the comparison of the two, it can be found that the construction schedule requires the completion of the guardrail of the main girder of the bridge, but the actual completed guardrail on the site only the first seven spans of the right girder and the ninth and ten spans of the right side, and the construction progress has a lagging phenomenon [10].

After investigation, the main reasons for the construction progress lag are: (1) the bridge technicians invest less and the construction machinery is insufficient; (2) the designer calculates the calculation of the slope earthwork is wrong, which makes the slope excavation progress lag and affects the overall construction progress. The measures taken are as follows: according to the reasons (1), it is suggested to increase the manpower and machinery input of the bridge project, ensure the completion of the task according to the construction schedule, update the actual construction progress of the site to the construction simulation data, and grasp the construction progress of the site construction regularly. According to the reason (2), the tilt photography technology and BIM technology are used to quickly and accurately calculate the remaining amount of the slope earth and rock excavation, so as to provide data reference for the slope excavation progress control.

**Table 3.** Construction progress of the guardrail.

| primary beam | Concrete volume ($m^3$) | completed amount ($m^3$) | rate of progress/% |
|---|---|---|---|
| 1 | 152.361 | 150.83 | 99 |
| 2 | 15 0.440 | 148.93 | 98 |
| 3 | 154.33 | 152.88 | 99 |
| 4 | 154.24 | 152.718 | 98 |
| 5 | 154.44 | 153.119 | 98 |
| 6 | 153.138 | 152.119 | 99 |
| 7 | 153.532 | 142.391 | 96 |
| 8 | 153.223 | 142.496 | 96 |
| 9 | 152.967 | 149.942 | 89 |
| 10 | 152.852 | 131.451 | 86 |
| 11 | 152.053 | 129.224 | 85 |
| 12 | 151.662 | 130.079 | 86 |
| 13 | 151.245 | 128.558 | 85 |
| 14 | 151.143 | 128.549 | 85 |
| 15 | 151.452 | 12.196 | 8 |
| 16 | 152.434 | 0 | 0 |
| 17 | 152.402 | 0 | 0 |
| 18 | 151.952 | 0 | 0 |

## 4. Conclusion

Based on the construction section of a high-speed project, this paper proposes a highway construction progress monitoring method based on inclined photography technology and BIM technology, and makes specific application analysis. The main contents and conclusions are summarized as follows:

Introduce the environment and language of the three major development methods of MicroStation, and select the most suitable Addins method for the project to develop the construction progress analysis plug-in. The plug-in includes three management modules, “build tree”, “comparison model” and “report”.

The construction progress analysis plug-in can automatically match the segmentation and calculate the three-dimensional real scene model and BIM model through the Boolean algorithm, get the actual construction progress report, and realize the construction progress monitoring of the highway project. The overall matching accuracy of the plug-in is 97.27%, which solves the problem that it is easy to escape from the real situation only by relying on the BIM model, and effectively reduces the workload, improves the degree of monitoring automation, and avoids the error caused by artificial subjective matching and calculation.

Combined with the visualization advantages of BIM software and the advantages of information integration, the actual construction progress obtained by the plug-in analysis is compared with the planned schedule BIM model, so that relevant personnel can find the construction progress deviation in time and adjust the subsequent construction progress.

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