Research on the Digital Twin Model of Fuchunjiang Hydropower Plant Based on 3D Laser Scanning Technology

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Abstract. With the development and application of 3D scanning technology, the efficiency and accuracy of 3D reverse modeling have been greatly improved. In this paper, 3D laser scanning technology is used to establish the 3D model of the hydropower house and main equipment of Fuchunjiang Hydropower Plant, which can truly restore the internal structure and equipment layout of the power station, and solve the difficulties in realizing the digital power station construction due to incomplete or missing drawings of the old power station. The 3D model of the hydropower house and main equipment of Fuchunjiang Hydropower Plant established in this paper not only forms the valuable virtual assets of the power station, but also lays the foundation for flood control emergency plan simulation and 3D maintenance training of the power station, which has a wide field of application with good prospects.

Keywords: Fu'ChunJiang Hydropower Plant, constructed hydropower station, 3D laser scanning technology, reverse modeling, high-precise modeling

1. Introduction

3D laser scanning technology is a new measurement technology in recent years. It has the advantages of high measurement accuracy, high measurement efficiency, and visualization of the measured object. Therefore, it has been widely used in domestic and foreign engineering fields, such as the reverse of pipelines, buildings, large equipment, etc., and deformation monitoring of tunnels, bridges, etc. It realizes the restoration of the measured object and lays a foundation for further visual analysis and application [1-3].

In order to check the construction quality, Ma Ben uses the 3D laser scanner to perform reverse modeling on the nodes of the comprehensive pipe gallery, which solves the problems of intuitionism and poor interpretation of the traditional as-built measurement results, and ensures the quality of the underground comprehensive pipe gallery [4]. Sun Fengchun applies the 3D laser scanning technology to the deformation monitoring of the bridge, which realizes continuous, high-precision, high-efficiency, and reliable deformation monitoring of bridge [5]. Li Xiaoshun, Feng Yi, Peng Wang use 3D laser scanning technology to scan the full section of the tunnel to detect and deal with the defects on the concrete surface, which can ensure the safety of the project. At the same time, a database of concrete surface defects has been accumulated providing a basis for subsequent research [6]. Fu
Jianwen, Zhu Kegang, Hu Jun combine with 3D laser scanning technology to realize the 3D reverse modeling of the old power station, Xin'anjiang Hydropower Station, which highly restores the internal environment of the power station, and effectively solves the problem that the old power station can’t be restored due to the loss of drawings [7]. Reference [8] introduces the application of 3D laser scanning technology in nuclear power plant operation and maintenance management, and points out that it will play an increasingly important role in information visualization and asset management. Reference [9] uses 3D laser scanning technology to establish 3D models of traditional architecture, which provides technical support for the protection of traditional architecture.

Therefore, 3D laser scanning technology has significant application effects in reverse modeling of various industries engineering. It can provide technical support for 3D modeling of established old power stations. This paper studies the reverse modeling of Fuchunjiang Power Plant's building structure and main equipments based on 3D laser scanning technology, which provides a foundation for the digital simulation of flood control and flooded plant emergency plans.

2. 3D Laser Scanning of Hydropower House and Main Equipments

In this paper, 3D laser scanning technology is used to obtain the point cloud data of Fuchunjiang power plant building structure and main equipments. This section mainly introduces the scanning equipment, range, and the layout of scanning sites.

2.1 Scanning Equipment and Range

In order to ensure the accuracy of 3D reverse modeling and restore the details of the real scene as much as possible, RIEGL vz1000 3D laser scanning imaging system produced in Austria is used to obtain the point cloud data of building structure and equipments. RIEGL vz1000 has a scanning accuracy of 300000 points/s, a scanning accuracy of 8mm (100m), a repeated scanning accuracy of 5mm, a maximum measuring distance of 1200m, a nearest measuring distance of 1.5m, an angular resolution of 0.0005°, a horizontal scanning range of 0° to 360° and a vertical scanning range of +60° to -40°. RIEGL vz1000 has the characteristics of ultra-high speed data acquisition, high modeling accuracy and wide scanning field angle, which can quickly and accurately identify the target details.

In order to fully show the layout and characteristics of the hydropower house and its interior, the scanning range includes the outer contour of the hydropower house, the generator floor, the middle floor, the turbine floor and the gallery floor.

2.2 Layout of Scanning Site and Measurement

In order to obtain the point cloud data comprehensively and completely, it is necessary to arrange the scanning sites reasonably. If the scanning sites are not enough, there will be scanning blind area and splicing black hole. If there are too many scanning sites, the scanning efficiency will be reduced and splicing error will be accumulated. Generally, the scanning sites should follow the following principles: (1) the scanning sites should avoid the opaque object as far as possible; (2) the distance between adjacent sites should keep 20% ~ 30% overlap; (3) the scanning distance should not exceed 30m. According to the characteristics of the building structure and internal equipments layout of Fuchunjiang Hydropower Plant, 273 scanning sites are set, including 23 sites on the outer contour of the hydropower house, 39 sites on the generator floor, 118 sites on the middle floor, 64 sites on the turbine floor and 29 sites on the gallery floor.

The point cloud data obtained by different scanning sites are data in different coordinate systems. These data need to be spliced to be converted to the same coordinate system, so as to obtain the complete 3D model information of plant building and main equipments. Therefore, the modeling accuracy of 3D model depends on the splicing accuracy of point cloud data to a certain extent, and the splicing accuracy of point cloud data depends on the coordinate accuracy of scanning site. In order to improve the splicing accuracy of scanning data, the coordinates and elevation of each scanning site should be measured, and the measurement accuracy should not be lower than the technical requirements and accuracy of root control point.
3. 3D Reverse Modeling of Hydropower House and Main Equipments

After the completion of 3D laser scanning, the data obtained is point cloud data, which needs to be spliced, denoised, extracted building contour and texture data in order to establish the real 3D model of hydropower house and main equipments.

3.1 Data Processing and Splicing

The point cloud data scanned by the scanner at each site is a local coordinate system with the coordinates of the site as the zero point. The coordinate system of the point cloud data obtained by each site is independent, and they need to be transformed into the same coordinate system through splicing technology. The splicing methods mainly include target based splicing, feature point based splicing, measurement point based splicing and hybrid splicing [4]. According to the characteristics of the internal structure of the plant, the common feature points can be directly and conveniently selected, so the feature point based splicing method is adopted in this paper.

The point cloud data is processed and spliced in the 3D scanner's own software RiScanPro. After completing the parameter setting, the coordinates of the scanning site are input, and the splicing orientation is carried out according to the common feature points between the point cloud of each site. After the splicing, the site coordinates and the spliced coordinates are compared to check the accuracy of splicing. If it does not meet the requirements of splicing accuracy, it needs to be spliced again.

In the process of scanning, there are some interferences in the environment, so there are many noise points in the collected point cloud data. Therefore, it is necessary to process these noise points to generate high-precision 3D models. The general preprocessing method is to delete them manually.

Due to the large amount of point cloud data of hydropower house and main equipments, we export the point cloud data of each layer in blocks. The data format is .las. The spliced point cloud data of hydropower house is shown in figure 1.

![Figure 1. Point cloud renderings of hydropower house](image)

3.2 3D Modeling

In the point cloud, the point, line, surface, cylinder and tetrahedron are used to fit the object [10], so as to obtain the high-precision outer contour model of buildings and equipments. In this paper, 3D Max is selected as the modeling software, and the point cloud data of the hydropower house and each layer are input into 3D Max software. By constructing triangular patches to approach the outer surface of the scanned object, the standard model of the scanned object is established.

Due to the complex structure and geometric shape of hydropower house and main equipments, the amount of point cloud data collected is huge. Directly generating the model will cause the oversized model and the slow generation speed. The general processing method is to choose the point cloud data properly on the premise of ensuring the modeling accuracy, or reduce the number of triangular patches by increasing the interval of triangular patches.

After obtaining the outer contour models, texture mapping is required on the outer surface of the model to obtain the real 3D model consistent with the entity vision. Therefore, it is necessary to use a high-resolution digital camera or video camera to take pictures of objects on the spot. The pictures should be taken upright as far as possible and marked on the topographic map for easy searching.
Photoshop software is used to cut, even color, splice the pictures, and then paste it on the building frame model to form a real and beautiful 3D model. The outer contour and 3D models of hydropower house, generator floor, middle floor, turbine floor and gallery floor are shown in figure 2 to figure 6.

(a) Outer contour model of hydropower house  (b) 3D model of hydropower house

**Figure 2.** Outer contour and 3D models of hydropower house

(a) Outer contour model of generator floor  (b) 3D model of generator floor

**Figure 3.** Outer contour and 3D models of generator floor

(a) Outer contour model of middle floor  (b) 3D model of middle floor

**Figure 4.** Outer contour and 3D models of middle floor

(a) Outer contour model of turbine floor  (b) 3D model of turbine floor

**Figure 5.** Outer contour and 3D models of turbine floor

(a) Outer contour model of gallery floor  (b) 3D model of gallery floor

**Figure 6.** Outer contour and 3D models of gallery floor
4. Conclusions
In this paper, the 3D model is established for Fuchunjiang Hydropower Plant, which truly shows the internal environment of the hydropower station. The 3D model forms a valuable "virtual asset", and lays a foundation for the digital construction of Fuchunjiang Hydropower Plant.

Based on the 3D model, the flood control and flooded plant emergency plans can be simulated in advance. By assisting the hydropower station to implement the flood control plan, the flood emergency can be handled orderly and efficiently, and the loss of the disaster can be minimized. In addition, through the combination of virtual and real, based on the real and beautiful 3D model, 3D maintenance training can be carried out for operation and maintenance staff. The maintenance level of operation and maintenance staff can be improved.

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