Preliminary Study of Close-Range Photogrammetric Three-dimensional Reconstruction in Engineering Detection

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Abstract: Because there are many measurement points in the large civil engineering structures, and the traditional contact measurement method can not meet the requirements of fully reflecting the structural form, the applicability of close-range photogrammetric three-dimensional reconstruction technology in engineering detection is studied. Digital coded mark points are arranged on the reinforced concrete T-beam, and image sequences with a certain overlap ratio qre collected. In the three-dimensional reconstruction software, the structure is reconstructed with high quality and high precision. The three-dimensional reconstruction model and structure are compared in the crack and the size precision. From the comparison results, it can be concluded that close-range photogrammetric three-dimensional reconstruction technology has high measurement precision, can meet the requirements of the test structure and can directly display the physical information of the structure and surface crack. It would lay the foundation for further research and application of close-range photogrammetric three-dimensional reconstruction.

Keywords: Close-range photogrammetry; Three-dimensional reconstruction; Engineering detection

1. Introduction

Understanding the inherent laws of structural deformation and the state of the structure are the important problems that people care about in the engineering. Due to the fatigue effect and the material of the structure, the bearing capacity of the structure will be decreased under the long-term change of load. Cracks may appear at the most unfavorable position of the structure and will be further developed with the continuous action of the load. It can make the bearing capacity of the structure further decrease and endanger people's lives and property safety [1]. It is difficult to measure the large civil engineering structures with the traditional contact measurement method, but close-range photogrammetric three-dimensional reconstruction technology has the advantages of measuring complex objects. In order to study the applicability of close-range photogrammetric three-dimensional reconstruction technology in engineering detection and determine whether it can meet the requirements of structure tests, we conduct experimental research on close-range photogrammetric three-dimensional reconstruction technology.

2. The Theory of Close-Range Photogrammetric Three-dimensional Reconstruction

Close-range photogrammetric three-dimensional reconstruction technology is using three-dimensional reconstruction software to process a certain overlap degree of image sequence which is captured by camera with known internal parameters (focal length, principal point, distortion parameters), to calculate the 3D coordinates of the surface point of the structure and reconstruct 3D surface model of structure [2-5]. Before the test, digital coded mark points should be set to improve the accuracy of three-dimensional reconstruction. The layout of the digital coded mark points will affect the calculation accuracy and the measurement accuracy [5]. The marked point which we used is passive luminous mark point. Based on the measurement principle of white light speckle, the position of the mark points can be calculated, so as to realize the automatic recognition of the mark points and the corresponding serial number [6,7]. Digital coded mark points as shown in Figure.1.

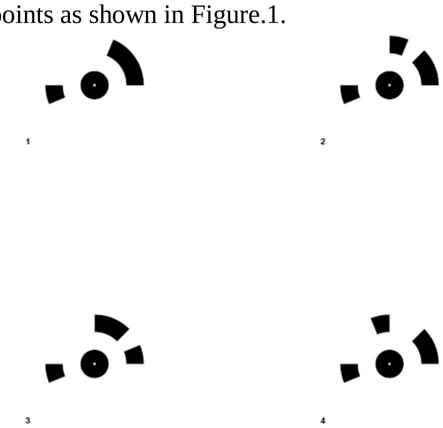

Figure 1. Digital coded mark points

3. Measurement Test

This test has been carried out on the reinforced concrete T-beams which have been damaged. Before the image data acquisition, the T-beam is required to paste 16 bit digital coded mark points every 30cm distance in order to improve the accuracy of three-dimensional reconstruction of the model. The density of the mark point is determined according to the shooting and surrounding environment conditions. Arrangement of mark points in the middle and end of T-beam as shown in Figure 2 and Figure 3.

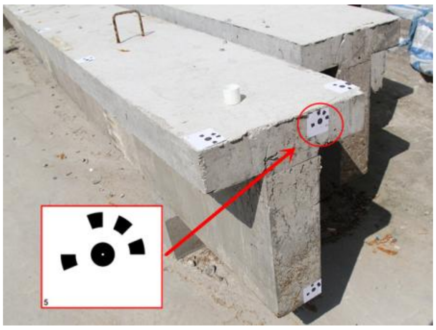

Figure 2. Layout of mark points in the end of T-beam

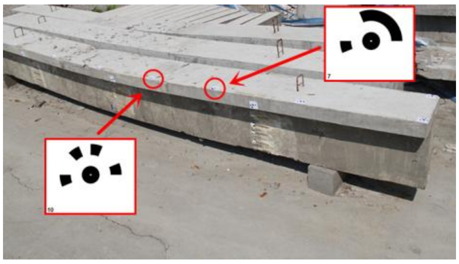

Figure 3. Layout of mark points in the middle of T-beam

It is necessary to ensure the adjacent photos have a high degree of overlap. Especially for the structure without mark points, it is necessary to ensure that the adjacent two photos at least have 1/3 overlap. Three-dimensional reconstruction requires that the captured images can cover all the texture information of the structural surface, and the angle of each shot is as much as possible.

4. Image Processing and Result Comparison

4.1. Three-dimensional model reconstruction

According to the images which have a high degree of overlap, the mark points are identified by three-dimensional reconstruction software. From different shooting angles to reconstruct the three-dimensional coordinates of the surface of the structure, according to the location of the camera, a series of coordinate transformation relations have been established. Establish the correspondence between the point in the image and the point in the space to reconstruct the three-dimensional model [5]. In the three-dimensional reconstruction software, the point cloud of the structural surface is generated. Remove the irrelevant noise point and triangular mesh processing makes adjacent points connected as a whole. Paste surface texture in the triangular mesh to create three-dimensional reconstruction model.

4.2. Texture characteristics comparison

In the process of three-dimensional reconstruction, the high quality and high precision mode is used to carefully display the surface texture information of the structure. Especially for the crack observation, the method can improve the efficiency and avoid the crack observation can not be successfully carried out in some special environment. Comparison of Shape and crack as shown in Figure 4 and Figure 5.

Figure 4. Comparison of object and model

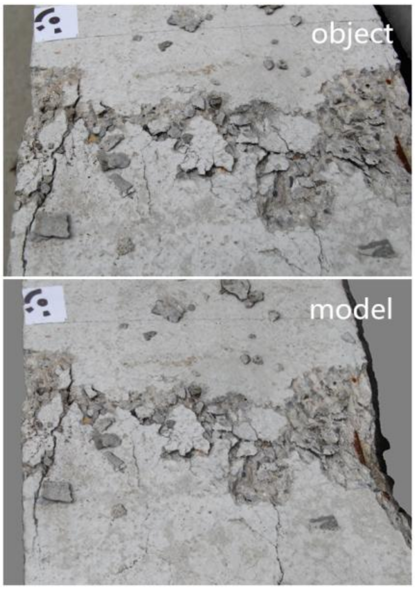

Figure 5. Crack comparison of object and model

From Figure.4 and Figure.5, we can see that the three-dimensional reconstruction model can carefully display the surface texture information of the structure. By comparing the actual crack image with the model, we can draw a conclusion that pictures and three-dimensional reconstruction models of overall and detail almost no difference, and the accuracy of the crack observation has reached the 1mm level. As a non-contact detection method, close-range photogrammetric three-dimensional reconstruction technology avoid the crack observation can not be successfully carried out in some special environment. This allows us to further study the measurement of the size of the crack at the later stage. Therefore, and the method can be further applied to the detection of cracks on the surface of large civil engineering structures.

4.3. Size precision comparison

In order to measure the size precision of the three-dimensional reconstruction model, the size of the model have been measured. The size precision of close-range photogrammetric three-dimensional reconstruction technology is an important measurement to accurately reflect the surface state of the structure. The basis for further research and application of close-range photogrammetric three-dimensional reconstruction technology is whether this technology has high precision in size. If the size precision can be controlled within 5%-10%, it can meet the requirements of engineering application. Due to the existing plastic deformation in the cross section of the structure at the middle point of a span, the cross section is regarded as the assessing position of size measurement to evaluate the size precision of close-range photogrammetric three-dimensional reconstruction technology. And the middle span deflection should be measured simultaneously.

The results as showed in Table 1, Figure 6 and Figure 7 illustrates that close-range photogrammetric three-dimensional reconstruction technology has high accuracy, can reflect the actual form of the structure. The size precision can be controlled within 5%, it meets the requirements of engineering application. Compared with other measurement methods, the three-dimensional reconstruction model is not only limited to measure the width and height of the measurement, it can measure the dimension distance in each direction, and the data can be used repeatedly whether it is now or later. For engineering detection, we can compare the different three-dimensional reconstruction models which are generated at different time. From the comparison results, it can be concluded that the change of the structure with time can be obtained. When the structure has some problems and leads to abnormal deformation, we can use the set of a critical value for the early warning of structural lesions. In this way, it can make the engineering detection more reliable and more efficient.

Table 1. Comparison of size precision

	Object size (cm)	Model size (cm)	Error (cm)	Error percentage (%)
Total length	400.9	400.9	0	0
Width of cross section	30.25	30.80	0.55	1.8 %
Height of cross section	39.95	40.32	0.37	0.92 %
Deflection	7.3	7.49	0.19	2.6 %

Figure 6. Deflection measurement

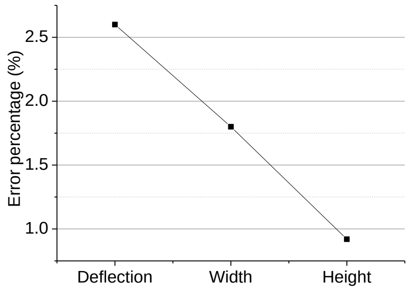

Figure 7. Error percentage

5. Conclusion

Through preliminary study of close-range photogrammetric three-dimensional reconstruction, this paper gives the following conclusion:

In the process of image capturing, you need to select the appropriate angle. If the software does not accurately identify the location and angle of the camera, the 3D coordinates of the surface points of the structure will be calculated incorrectly. It will greatly affect the measurement accuracy of the latter.

Close-range photogrammetric three-dimensional reconstruction technology has high accuracy, can meet the test accuracy requirements. This method can obtain a large number of physical and geometric information of the structure in a short period of time, especially suitable for the measurement of the complex structure [8].

As a non-contact detection method, close-range photogrammetric three-dimensional reconstruction technology avoid the crack observation can not be successfully carried out in some special environment. And the method can carefully display the surface texture information of the structure. Therefore, it is practicable to do further research and application of close-range photogrammetric three-dimensional reconstruction.

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