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Study on Application of Close-Range Photogrammetric 3D Reconstruction in Structural Deformation Measurement

Tengjiao JIANG
School of Civil Engineering, Chongqing Jiaotong University, Chongqing, 400074, CHINA

Abstract: For large civil engineering structures, many touch sensors are often required to be arranged in the key position of the structure. This will lead to not only the sensor data transmission is difficult, but also the finite measurement points is difficult to fully reflect the actual state of the structure. Based on laboratory studies of close-range photogrammetric three-dimensional reconstruction, we further put it applied to actual civil engineering structure. The three-dimensional surface deformation of the road is simulated by placing objects with different thickness, and the improved image acquisition method is used to collect the image of the road. Three-dimensional reconstruction models of two working conditions are established in the software. Based on the point data extracted from the surface of the three dimensional reconstruction model, the Geomagic Qualify software was used to compare three-dimensional fitting surfaces of the two working conditions. Finally, we get the deformation chromatogram of each condition. The deformation of the surface of the road is directly and accurately reflected in the deformation chromatogram, and the size is close to the thickness of the object. It would lay the foundation for further research and application of close-range photogrammetric three-dimensional reconstruction.

Keywords: Close-range photogrammetry; Three-dimensional reconstruction; Structure deformation measurement

1. Introduction

Structural health monitoring is a very important part in the process of structure operation and maintenance. The surface of the structure will generate micro deformation in front of a major damage. Compared with the traditional observations which are based on a point, close-range photogrammetric three-dimensional reconstruction technology is using three-dimensional reconstruction software to process a certain overlap degree of image sequence to reconstruct three-dimensional surface model of structure [1-5].And this technology 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 [6]. Therefore, in order to better understand the applicability of close-range photogrammetric three-dimensional reconstruction technology in structural engineering and evaluate whether it can accurately reflect the three-dimensional surface deformation of the structure, we conduct experimental research on close-range photogrammetric three-dimensional reconstruction technology.

2. Close-Range Photogrammetric Test

Prior to this, the exploration test of close-range photogrammetric three-dimensional reconstruction was carried out in the laboratory. At this time, our experiment was carried out in an outdoor venue. The test object also changed from the T beam to the road which is 23 meters long and 3 meters wide, as shown in Figure.1. And in order to adapt to engineering application and also to speed up the image acquisition efficiency, we changed the original shooting mode into a one-way shooting mode which is perpendicular to the center line of the road.

Figure 1. Close-range Photogrammetry of the Road

In order to improve the dimensional accuracy of the three-dimensional reconstruction of the model, the 16 bit digital coding marks were used in the previous test of

concrete T beam. But there are a lot of limitations in the 16 bit digital coded mark points. First of all, the coding mark points are short of practical application in the engineering. In the second, it is required that the number of digital coding mark points should be assigned to each measurement. This is not practical for large civil engineering structures, and also greatly increase the workload of the staff. At the same time, it is difficult to determine the size of the mark points for different civil engineering structures. If the size is too small, it can not accurately identify the location of the mark points and the serial number of the markers. Moreover, the paper marks are vulnerable to rain and other environmental factors.

Therefore, we are trying to find a solution which can not only guarantee the dimensional accuracy of the three-dimensional reconstruction of the model, but also reduce the huge workload in the prophase. So we take some change in this experiment. We use artificial marking points to replace the original marking points, and only draw the mark points at the key points of structure. The distance between the adjacent mark points can be satisfied with the camera, and the two mark points can be taken simultaneously. In the three-dimensional reconstruction, the method of manually marking mark points is adopted. Compared to the paper marking point, the benefits of artificial marking point is not affected by rain and other environmental factors. The size of artificial marking point can be determined according to the actual civil engineering structure, which is not limited by the printer, and can be reused for many times. The artificial marking point as shown in Figure.2.

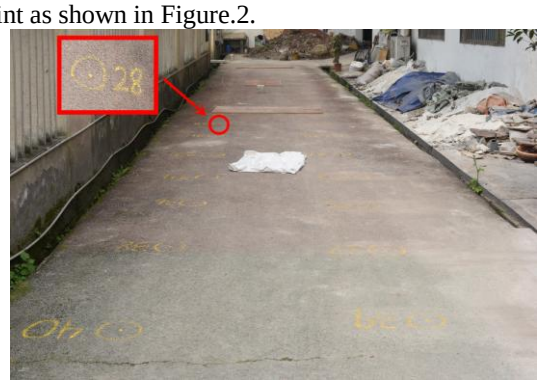

Figure 2. The artificial marking point

The test of close-range photogrammetric three-dimensional reconstruction were divided into two conditions. The first condition is not to place any object on the road, in order to simulate the initial state of the road, as shown in Figure.3. According to the previously drawn marking points, we use the camera to shoot the road on the both side. In the process of shooting to ensure that the collected image contains at least two points, the purpose is to make the post-processing of three-dimensional modeling software easier to identify the specific location of the camera, reduce the probability of the location recognition error and improve the accuracy of modeling.

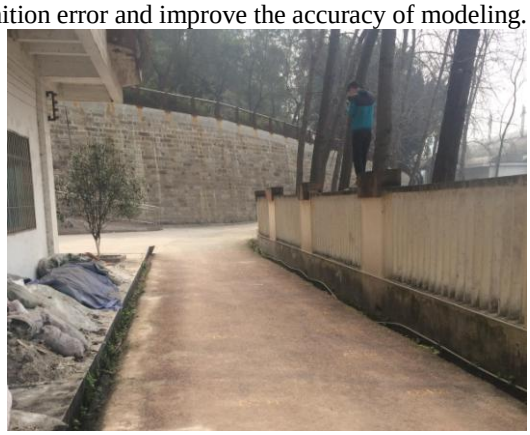

Figure 3. Initial condition of road

In the second condition, we place 3 pieces of wood, a concrete block, and a piece of plastic film on the road to simulate surface deformation, and to explore whether the three-dimensional reconstruction can reflect the local surface deformation of the road, as shown in Figure.4. In the same way, the image of the road under second working conditions is obtained.

Figure 4. Local deformation condition of road

3. Three-dimensional Modeling and Result Comparison

3.1. Three-dimensional model reconstruction

In the three-dimensional reconstruction software, the marking points on the road of all photographs are identified manually, as shown in figure.5. Then the point cloud

models are established for the two working conditions in the three-dimensional reconstruction software. 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 models. In the process of manually identifying marking points, the accuracy of the position of the marking points should be paid attention to. The marking point which is far from the camera position should not be marked. Otherwise, it is more likely to lead to a decrease in the dimensional accuracy of the model.

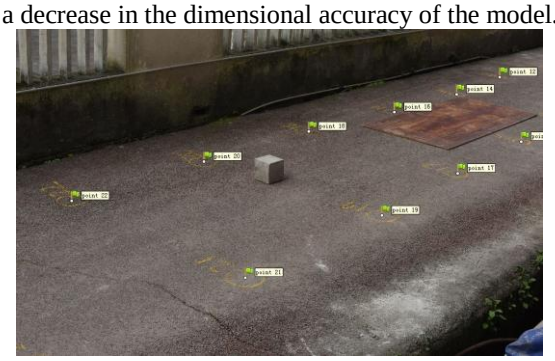

Figure 5. The manually identified marking points

3.2. Texture characteristics comparison

Close-range photogrammetric three-dimensional reconstruction technology can not only restore the structural shape, but also paste surface texture in the triangular mesh. The fine degree of texture is related to the selected model of the three-dimensional reconstruction software. The texture makes close-range photogrammetric three-dimensional reconstruction technology not only explore the morphological changes in object space. Texture comparison as shown in Figure.6.

3.3. Three-dimensional Surface Comparison

In order to observe the change of the road surface directly and reflect the objects which represent the different deformation. We put the point cloud data which is extracted from the surface of the three dimensional reconstruction model into the Geomagic Qualify software. After a series of treatment, the road without any object to be placed as a reference surface, and the road with objects to be placed as a test surface. And the Geomagic Qualify software was used to compare the three-dimensional surface of the road [7,8]. Finally, we obtain the deformation chromatogram.

The deformation chromatogram of three-dimensional fitting surface of two conditions as shown in Figure.7. From the chromatogram, we can directly observe that close-range photogrammetric three-dimensional reconstruction technology can accurately reflect the local surface deformation. And the thickness of the wood be directly reflected. But in the experiment, it is found that the 3D reconstruction model is difficult to reflect the shape of the road surface with smooth or no texture. Such as figure.7, the upper left corner of the blue region. We can get information from the chromatogram that the blue region have caved in, but in fact the region has not changed in the experiment. The reason is that the area is smooth and no texture. Therefore, in the latter part of the further study, it is needed to find a solution to this problem. At the same time, it is also found that in the process of image acquisition, it is required to adjust the exposure degree, and the high exposure will also affect the dimensional accuracy of the three-dimensional reconstruction and the texture of the model.

Figure 6. Texture comparison

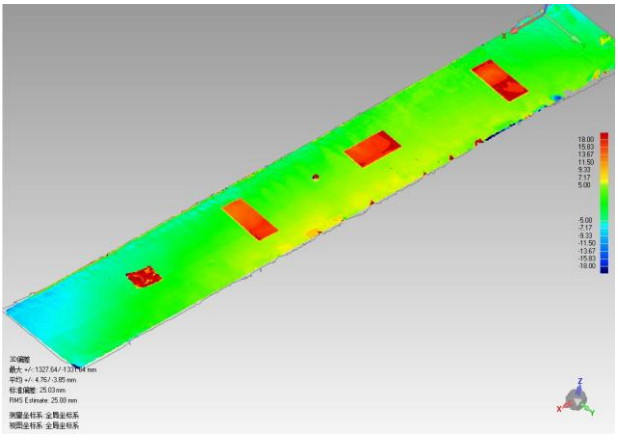

Figure 7. Deformation chromatogram

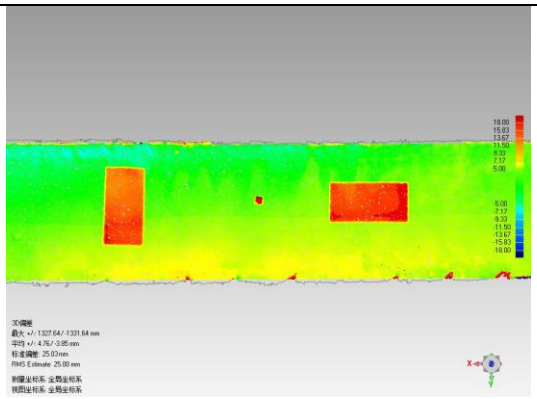

Figure 8. Deformation chromatogram

For concrete blocks and wood placed in the middle section, the different color depth directly reflect the difference thickness of the two objects, as shown in figure.8. It would lay the foundation for further research of close-range photogrammetric three-dimensional reconstruction in deformation measurement of three-dimensional surface.

4. Conclusion

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

It is useful to draw the mark points in the key parts of the structure to replace the original pasted paper marking points. And dimensional accuracy of three-dimensional reconstruction will not be reduced. But the problem is that the work of the manual identification of marking point is larger, and the efficiency is low. Therefore, it is needed to find a more feasible marking method for the application of large scale civil engineering structures.

Through the comparison in the Geomagic Qualify software, the deformation of the surface of the road is directly and accurately reflected in the deformation chromatogram, and the size is close to the thickness of the object. Therefore, it is practicable to do further research and application of close-range photogrammetric three-dimensional reconstruction.

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