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Rapid Detection Method of Local Leakage Water in Shield Tunnel Based on Three-Dimensional Laser

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Abstract: *In order to realize the accurate detection of water leakage points in shield tunnel, a rapid detection method for local water leakage in shield tunnel is designed by introducing three-dimensional laser technology. Place the three-dimensional laser scanner in a relatively stable position to collect local information of the shield tunnel; The collected information is denoised to realize the diagnosis and location of tunnel leakage. Through comparative experiments, it is proved that the test results of the designed method are more suitable for the actual situation, that is, the test results are more accurate.*

Keywords: *Three dimensional laser; Detection method; Fast; Water leakage; Local; Shield tunnel*

1. Introduction

Shield tunnel is the most common construction technology in tunnel engineering, which is affected by many factors. After the construction and completion of shield tunnel engineering, the shield tunnel must be continuously monitored to ensure that the deviation from the design value is within an acceptable range. Water leakage is one of the common problems in the quality inspection of tunnels, and it is also the core element that induces the instability and cracks of the main structure of tunnels. Water leakage will cause the instability of tunnel structures, thus inducing large-scale safety accidents. In order to reduce the impact of this disease on shield tunnel engineering, this paper will introduce three-dimensional laser technology and design a rapid detection method for local leakage of shield tunnel. In this way, the disease can be treated in time and the economic losses and casualties caused by leakage can be reduced.

2. Local information collection of shield tunnel based on 3D laser

In order to realize the rapid detection of local leakage of shield tunnels, three-dimensional laser scanning technology is introduced to collect local information of shield tunnels [1].

Before data collection, survey stations should be arranged according to the actual situation of shield tunnel. On the premise of ensuring the scanning quality of point cloud, the number of observation stations should be reduced as much as possible, so as to reduce the splicing error of point cloud. At the same time, according to the needs of the project, set the best scanning resolution. Considering the limited ranging accuracy of the three-dimensional laser scanner, each measuring point must be converted after each area is completed, so that the data between each measuring point is independent of each other. Therefore, at least three targets need to be set between the two measuring points to facilitate the splicing of subsequent data. After the preparation work, you can start scanning the tunnel.

During the acquisition process, place the 3D laser scanner in a relatively stable position. The scanning equipment is used to collect the size and position information of the physical object and generate the point cloud data. Under the condition of sufficient light, place the target at the predetermined position and keep it within 15 meters of the scanning equipment. Install the equipment, configuration file, resolution, scanning distance and other parameters. According to the requirements of on-site scanning, set the scanning resolution of 44mpts, 360 ° horizontal scanning and 300 ° vertical scanning. After each scan, it is necessary to open the top of the target to expose the reflection target

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inside the target, install the total station on the observable target, measure the reflection target, and record its point information according to the specifications. Define the position of the instrument as the scanning center, establish an X-Y-Z coordinate system on site, and set the transverse scanning direction of the instrument as X, the longitudinal scanning direction as Z, and the oblique scanning direction as Y. As shown in Figure 1 below.

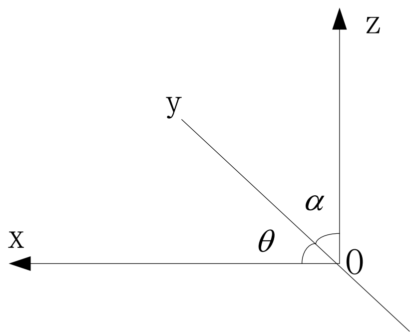

Figure 1: Scanning coordinate system of shield tunnel based on 3D laser

In Figure 1 above, α and θ represent the included angles between oblique scanning and vertical and horizontal directions respectively. Collect scanning data, as shown in the following calculation formula.

$$\begin{cases} X = \mathrm{S}\cos\alpha\cos\theta \\ Y = \mathrm{S}\cos\alpha\sin\theta \\ Z = \mathrm{S}\sin\alpha \end{cases} \tag{1}$$

In formula (1): S represents the three-dimensional laser scanning range. The scanning information in the three directions of X, Y, and Z is collected, and the information scanning process is regarded as a three-dimensional laser scanning process on the ground based on laser ranging and angle measurement of non-cooperative targets. The measurement of distance, slant distance and reflection intensity can obtain a large amount of point cloud information. In this way, the collection of local information of the shield tunnel is completed.

3. Diagnosis and location of tunnel water leakage based on information processing

Using point cloud data and Cloudworx plug-in, you can get the plan, elevation and profile of the shield tunnel, and thus understand the size, shape and internal equipment layout of the tunnel. On the basis of the above design content, the collected point cloud data is spliced. The splicing technology is to match the scanned data of multiple sites under specific constraints, and on this basis, the point information is spliced to form a complete point cloud. In the process of operation, you need to create a registry in the interface first, add the adjacent point data to the registry, add restrictions, and merge the point cloud data.

In order to avoid the interference of noise information in the collected information to the local disease diagnosis of shield tunnel, the collected information should be denoised. Through the optimization of the collected point cloud data, the noise to be removed is screened out, and the selected point cloud data is quickly removed through the deletion function of the software. Before scanning, first select the color information and apply the collected photos to the side item column. If they are not saved, the current grayscale data will be displayed. After storage, the system will automatically match the color information of the point cloud, so that each point has the corresponding RGB information, output the corresponding data, and complete the data preprocessing. The processing process is shown in the following calculation formula.

$$P = \sum_{i>1}^{m} \omega_{X,Y,Z}(\delta_i) \tag{2}$$

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In formula (2): P represents the denoising process of the collected information; ω represents the original information; δ represents the observation parameter; i represents the boundary point; m represents the point cloud splicing error. Extract the feature information, and match the feature information with the local image of the shield tunnel. During the matching process, use the Cy-clone 9.1 software and the Cutplane slicing tool in the software to slice the point cloud data horizontally and vertically. The number of slices can be Depending on the specific situation, in this way, the monitoring end can clearly observe the shape of the specific measuring point of the structure. On this basis, the software is used to perform grid modeling processing on the collected point cloud data. Using the constructed model, all the collected information can be constructed into a digital engineering leakage model according to the map. The process is shown in the following calculation formula.

$$Q(u)=\frac{\sum_{n>1}^{n} B_n W_n}{\sum_{p>1}^{p} A_p W_p} \tag{3}$$

In formula (3): Q represents the matching of local feature information with the original image; u represents the matching node; B represents the top plate weight factor; W represents the scanning surface area; A represents the local image coverage area; n represents the positioning axis; p represents the splicing common point [2]. The matching result is derived, and the result is used as the local leakage water localization result of the tunnel, and the result is adapted to the tunnel spatial structure. On this basis, the template released by Cyclone on the monitoring terminal interface is used to assist the use of Tru-View software to publish the matching of local feature information and the original image. In this way, the detection and diagnosis of local leakage of the tunnel is completed.

4. Comparative experiments

In order to test the effect of the rapid detection method designed in this paper in practical application, the following will take a shield tunnel project in an area as an example to test the feasibility of this method.

The rapid detection method of local leakage of shield tunnel based on infrared detection technology is introduced as the traditional method, and two methods are used to detect the leakage of tunnel. Take the manual detection results as a reference, and count the experimental results, as shown in Table 1 below.

Table 1: Comparison results of rapid detection methods for local leakage of shield tunnels

Tunnel section	Manually detect leaking points (places)	The method of this paper detects the leakage point (place)	Traditional method to detect leakage point (place)
K125m+K128m	2	2	2
K204m+K206m	3	3	2
K217m+K219m	1	1	0
K352m+K353m	0	0	0
K450m+K458m	1	1	1

From the above results, it can be seen that the leakage point detected by this method is completely consistent with that detected manually, and the traditional method is missing. This proves that the detection method based on 3D laser designed in this paper has better detection effect in practical application.

5. Conclusion

Taking a shield tunnel as an example, this paper designs a rapid detection method of local leakage water in Shield Tunnel Based on three-dimensional laser, which is feasible after testing. Therefore, this method can be popularized in relevant engineering fields to reduce the economic losses of engineering construction caused by water leakage diseases in this way. Through this research, it is clear that the three-dimensional laser scanning technology has many advantages such as fast scanning speed and high

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measurement accuracy. The reasonable application of this technology can realize the comprehensive scanning and detection of the operating tunnel. Based on the image characteristics of the three-dimensional scanning, this method can not only detect the leakage points, but also detect the leakage water at different detection points. In this process, the position of water seepage can be accurate to the millimeter level, and can also be calculated by numbers. In a word, using three-dimensional laser scanner to detect the sensing layer of the Internet of things has the advantages of real-time and automation, but in order to promote this method in the relevant fields of the market in a real sense, we should also increase the investment in the research of relevant fields on the basis of the existing work, optimize and improve the design results in this way, and provide help for the standardized implementation of the detection work.

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