Research on Tunnel Support Deformation Based on Camera and Digital Speckle Improvement Technology

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Abstract. This paper mainly studies the measurement method of tunnel support deformation. On the stability of the rock to make a preliminary judgment. The use of simulated light source laser data acquisition, the use of digital image processing circle fitting spot positioning method. Reduce the use of lengthy algorithm to a certain extent, reduce the processing time of the data, and measure the position of the spot coordinates and radius. Show the changing rules of light spot. Improved digital speckle method to solve the pixel and length unit conversion problem. In the analysis of the accuracy of a certain elaboration.

Introduction

There are many safety problems in tunnel construction and monitoring that need to be addressed. In this study, the ONVIF protocol based on the deformation monitoring system is used to add the network server for analyzing and transmitting the data in the video module and transmit the monitoring results to the relevant departments for analysis and processing.

Deformation Monitoring System Related Technology

Overall Design

Digital image processing technology prepares the collected images, as far as possible to reduce the use of redundant algorithms. Using the cftool processing toolbox for curve fitting analysis, the degree of data can be visually reflected the network camera with the ONVIF protocol is transmitted to each tunnel management station via an optical transceiver and transmitted to the traffic bureau. The overall design ideas shown in Figure 1.

System Program Implementation

This study will be installed in the monitoring of the deformation of the network monitoring of the network camera, and in the deformation of the video analysis module to increase the web service server used to detect and analyze the real-time status of the highway tunnel staff can be through the PC side to view the highway sections and tunnels Of the deformation and through the optical transceiver and data transmission equipment to the Traffic Authority. Schematic diagram shown in Figure 2.

Figure 1. Overall design road map.
The model three-dimensional map is shown in Figure 3. The model will be different degree of interference, the spot will be different degrees of movement, in a day to change the location of the spot to do experiments, analysis of different time periods, different degrees of movement of the spot position changes. And the change trend of the measured spot and the moving distance of the manual interference light source are compared and the accuracy is analyzed.

**Introduction and Analysis of Deformation Monitoring Algorithm**

At present, there are a variety of light spot positioning research methods. In this paper, the use of circular fitting spot positioning and digital speckle correlation method to monitor the deformation of the material. Use circle fit to measure the center and radius. The digital speckle correlation method is used to measure the deformation displacement.
This study takes several points to find a closed polygon and calculates the area of the polygon, approximating it as the area of the circle to be fitted, and calculating the radius of the circle. Find the longest two points in the polygon, and use the center of the two points as the center of the circle, calculate the area of these polygons, along the longest distance and change the center position by the domain value, the difference is the least The center of the circle. Shown in Figure 4.

Digital speckle correlation method is the basic principle is to compare the measurement before and after the two changes in the plaque map to obtain displacement and deformation information. And the measurement of environmental factors on the results of the impact of smaller.

The center coordinates can be calculated by means of digital speckle method. Complete the measurement point from pixel to mm coordinate transformation. The resolution of the image is radius and the length of a single pixel can be calculated. When the displacement of the center of the spot \((\Delta x, \Delta y)\) is the displacement of the center of the image on the image (in mm).

\[
\begin{align*}
\Delta x' &= \Delta x \times (25.4 / r) \\
\Delta y' &= \Delta y \times (25.4 / r)
\end{align*}
\] (1)

(2)

Experimental Results and Analysis

Data Analysis

The experimental model of the collection of pictures in the MATLAB software for noise reduction, in order to facilitate the better round fit. Data acquisition is a key step in deformation monitoring. Will transfer the data using MATLAB software cftool toolbox curve fitting, fitting chart shown in Figure 5.
Table 1. Center and Radius Data Sheet.

<table>
<thead>
<tr>
<th>Monitoring serial number</th>
<th>Measuring point (Pixels)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>(1)</td>
<td>1322.6</td>
<td>2573.6</td>
<td>129.0602</td>
</tr>
<tr>
<td>(2)</td>
<td>1347.1</td>
<td>2540.1</td>
<td>127.0602</td>
</tr>
<tr>
<td>(3)</td>
<td>1293.4</td>
<td>2624.9</td>
<td>121.4982</td>
</tr>
<tr>
<td>(4)</td>
<td>1394.8</td>
<td>2156.3</td>
<td>164.7750</td>
</tr>
<tr>
<td>(5)</td>
<td>1358.6</td>
<td>2066.8</td>
<td>152.3153</td>
</tr>
</tbody>
</table>

In the preparation of the round fitting procedure, the other two round fitting methods and the circular fitting method described in the text are used to compare the timetable as follows:

Table 2. Time Comparison Table.

<table>
<thead>
<tr>
<th>Method</th>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
<th>Time 4</th>
<th>Time 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 1</td>
<td>6.9490</td>
<td>6.7945</td>
<td>5.9480</td>
<td>6.4589</td>
<td>6.2971</td>
</tr>
<tr>
<td>Method 3</td>
<td>8.3100</td>
<td>8.4939</td>
<td>7.9790</td>
<td>8.2670</td>
<td>8.5629</td>
</tr>
</tbody>
</table>

According to the data in the table, we can see that the method used in the experiment is more efficient, and the processing of the picture and the fitting speed are relatively fast. It will be possible to avoid casualties and take remedial action.

Accuracy Analysis

In the precision analysis of the time between the need for the conversion between the pixels and the length of the pixels, according to the formula 1 can calculate the distance on the image spot movement. Spot displacement and actual displacement still need to be converted.

(1) According to the camera's digital zoom factor, the measured spot size reduced to convex lens imaging size. In fact, the area of each pixel on the picture is enlarged by digital zoom, so the displacement of the spot on the convex lens is

\[ \Delta x = \Delta x' / d \]. \hspace{1cm} (3)

\[ \Delta y = \Delta y' / d \]. \hspace{1cm} (4)

(2) Using the convex lens imaging principle and the triangular similarity principle, the relationship between the displacement on the spot image and the actual displacement is: \( \Delta x_1 \) is the horizontal displacement of the measuring point, and \( \Delta y_1 \) is the vertical displacement of the measuring point.

\[ \Delta l_x = \frac{u-f}{f} \Delta x = \frac{25.4(u-f)}{dfr} \Delta x \]. \hspace{1cm} (5)

\[ \Delta l_y = \frac{u-f}{f} \Delta y = \frac{25.4(u-f)}{dfr} \Delta y \]. \hspace{1cm} (6)

When the actual monitoring, the camera distance \( u \), the focal length \( f \), the digital zoom multiple \( d \) and the resolution \( r \) of the collected image are both known parameters, and the actual displacement of the measuring point can be obtained according to the formula (4) and (5). The distance between the movement of the picture and the displacement of the actual object can be compared.
Summary and Outlook

In this paper, under the guidance of the instructor, the deformation of the highway tunnel is studied. The model is used to simulate the real environment of highway tunnels. In this paper, the displacement deformation for the measurement, the use of MATLAB software for pictures and data processing. For data analysis and precision analysis, in order to achieve the monitoring of highway tunnels. But the processing time and accuracy of the data still need to be further improved.

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Reference