A Monitoring Method Based on Quantitative Analysis of Videos and Images

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Abstract. To discover the potential risks and to issue a warning is cost-effective to prevent or reduce the loss of geologic hazards. Remote sense technology plays an important role in the development of monitoring methods. In this paper, a monitoring system based on quantitative analysis videos and images is presented. There are three phases. Firstly, layout the monitoring marks as a grid. Videos are captured in the second phase. After that, images are extracted from the video and image processing algorithms about edge detection and center detection chosen by comparing examinations then used to get the current coordinate of the marks. The displacement of each mark is collected by calculation, and then used to display and predicate the trend of deformation.

Keywords. Deformation monitoring system; edge filter, quantitative analysis.

1. Introduction

Geographic monitoring is an important task in the prevention and control of geological disasters. Discover the potential risks by monitoring the research area and issue a warning is cost-effective. For this reason, there exist interests in developing methods that reduce the monitoring costs, risks, and complexity, increases the quality and accuracy.

There are varieties of monitoring methods for deformation that have been based on measuring the displacements. They can be divided into two categories, namely, remote monitoring and contact monitoring methods. GNSS is a typical remote method that is applied in the hazard monitoring field currently [1-2]. To get a robust accuracy, GNSS receivers should compose a stable net, and working schemes such as working hours, data processing algorithms should be met the requirements regulated in the standards or adjustment principles. The main disadvantages of this type of measurement are the high cost to build a monitoring system and high technology requirements as well as high labor intensity. Another remote method by using Total Stations and survey robots can achieve high accuracy of displacement semi- or automatic monitor. However, the application range has been restricted by the high investment of the devices, limited viewing angle, and other object occlusions [3]. The accuracy of contact displacements observation methods, such as fracture meter, wire displacement meter, and other devices depends on the working environments, the field suitability performance of the devices. And this kind of method is just available for local areas and does not entirely reflect the entire area.
In this paper, we propose a method to quantitatively analyze videos and images to reconstruct vector displacement of deformation areas. They are based on edge detection algorithms [4-5] and center point detectors. The method has the following strengths.

1. The working principle is much easy;
2. The installation and deployment are more convenient and economical.

2. Basic Technology
High definition video monitoring equipment has been used as auxiliary equipment for real monitoring. The videos and images provide adjusting for regulatory authorities from a macro perspective. Photogrammetry technology is a typical application of that, such as for dynamic mining subsidence monitoring [3]. Combined with enough ground control points, edge detection algorithms and center point detectors, videos and images extracted from the videos can be used for quantitative monitoring analysis.

When the deformation happened, the points in the deformation area move and appear displacements in the 3D coordination system. Absolute or relative displacements observed and deformation trend will be analyzed and simulated. To get a higher accuracy displacement of the whole monitoring areas, two basic principles should be followed: (1) More data about the area should be collected to reflect the real deformation; (2) The panorama plays as a reference if the capturing of data cloud is not implemented. The method presented in this paper collects coordinate sequences of marks in the monitoring periods and the distribution of the marks forms a grid that the axis follows or perpendicular to the direction of the main deformation. In this way, there are much more monitoring marks than traditional observation. The coordinate of the marks and relative displacements among the marks is the foundation for deformation analysis, while videos and panorama support the calculation.

This solution contains two parts, the hardware system and the software system.

2.1. The Hardware System
The hardware system consists of a data capture device and four kinds of points, namely observation stations, datum points, reference points and monitoring points.

1. Observation stations. The location of observation stations is the place where data capture devices are installed. They should have a great view angle of the whole area to ensure all monitoring points and reference points can be photographed. Observation stations can locate on the ground or aerial vehicle platforms, such as UAVs. It’s important to remain the stations unchanged and away from the influence area.

2. Datum points. No less than three datum points are selected outside the deformation influence areas to define the coordinate system of the whole work. The chosen follows some principles, such as the location should form a strong net and a broad vision, the foundation must be stable, etc.

3. Reference points and monitoring points. Reference points are stable points nearby the monitoring area that playing the role of reference objects and helping to get the relative displacement. Monitoring points reflect the change of deformation area. The marks of the working points are shown in figure 1.

2.2. The Software System
The function of the software system is to process all the data captured by the hardware system and creating conclusion reports. It contains three parts, (1) the coordinate transformation between space coordinate system and image coordinate system; (2) Equal interval image extraction from the videos; (3) Edge detection and center point detection in the image.
There are many mature open-source detection algorithms offered by software, such as filters like Hough [6], Robert, Prewitt [7], Sobel [8-9], Canny [10], or Laplacian [11]. The software MatLab supplies the common edge detection operators as tools for customs which greatly reduces the difficulty of graphics processing.

3. Models

3.1. Coordination System
To define the spatial reference of the whole system, two known control points $S_1$ and $S_2$ are worked as the foundation (if the 3D coordinate is needed, there must have three control points at least). The control points must away from the influence area and their coordination is determined by measurements with high quality, such as web RTK. Based on that, the coordinates of reference working points $P_1$, $P_2$, $P_3$, then be calculated, as shown in figure 2.

\[
\begin{align*}
    x_p &= \frac{x_{S_1} \tan \alpha + x_{S_2} \tan \beta + (y_{S_2} - y_{S_1}) \tan \alpha \tan \beta}{\tan \alpha + \tan \beta} \\
    y_p &= \frac{y_{S_1} \tan \alpha + y_{S_2} \tan \beta + (x_{S_1} - x_{S_2}) \tan \alpha \tan \beta}{\tan \alpha + \tan \beta}
\end{align*}
\]

where $(x_{S_1}, y_{S_1})$ is the coordinate of $S_1$, $(x_{S_2}, y_{S_2})$ is the coordinate of $S_2$. 

Figure 1. Marks of the working points.

Figure 2. Reference points and datum points.
After the monitoring cooperative target is set in the monitoring area, panoramic photos of the monitoring area are captured at regular intervals (or extracted at regular intervals), while the camera parameters (such as image resolution, picture format, photo scale, the camera station) should remain the same in every shoot. Define the objection system of the picture (the origin, y and y axial). Get the objective coordinate of reference working points. The translation calculation formula is as follow,

\[
\begin{bmatrix}
\Delta x \\
\Delta y \\
\end{bmatrix}
= \begin{bmatrix}
\cos \alpha & -\sin \alpha \\
\sin \alpha & \cos \alpha \\
\end{bmatrix}
\begin{bmatrix}
\Delta x \\
\Delta y \\
\end{bmatrix}
+ \begin{bmatrix}
\Delta x \\
\Delta y \\
\end{bmatrix}
+ \begin{bmatrix}
\Delta x \\
\Delta y \\
\end{bmatrix}
\]

(2)

where \((x_1, y_1)\) is the coordination of the point in objective coordination system, while \((x_1, y_1)\) is the coordination in the photograph. \(\Delta x\) and \(\Delta y\) is the translate parameter in X and Y axis, in meters. \(\alpha\) is the rotation parameter, in radians. And \(m\) is scale parameter and has no unit. If the altitude is considered, then the translation calculate formula is as follow,

\[
\begin{bmatrix}
\Delta x \\
\Delta y \\
\Delta h \\
\end{bmatrix}
= \begin{bmatrix}
\frac{1}{\gamma X} & \frac{y Z}{\gamma X} & \frac{y Y}{\gamma X} \\
\frac{y Z}{\gamma X} & \frac{1}{\gamma Y} & \frac{y Y}{\gamma Y} \\
\frac{y Y}{\gamma Y} & \frac{y Z}{\gamma Y} & \frac{1}{\gamma Z} \\
\end{bmatrix}
\begin{bmatrix}
\Delta x \\
\Delta y \\
\Delta h \\
\end{bmatrix}
+ \begin{bmatrix}
\Delta x \\
\Delta y \\
\Delta h \\
\end{bmatrix}
+ \begin{bmatrix}
\Delta x \\
\Delta y \\
\Delta h \\
\end{bmatrix}
\]

(3)

where, \(m\) is the scale parameter and has no unit. \(\gamma X, \gamma Y, \gamma Z\) is the rotation parameter in three directions.

Since the two coordinate sequences of reference points is known, it’s easy to get all the parameters in equation 2 or equation 3 and determine the transformation model. Then, the homonymous dots then are extracted from the video from equal intervals are transformed by the model.

3.2. Monitoring Points Layout
The reasonable deployment location of the video monitoring equipment should be certain by the overall field perspective, distance and indivisibility conditions, as well as the reference working points. After reference points are established, the whole monitoring net is arranged as a grid based on the basic information of the research area and the demands of the monitoring task. The orthogonal axis is the same or perpendicular to the main deformation direction. Monitoring marks are deployed at the grid points. The whole layout is as shown in figure 3.

![Figure 3. The layout of all the marks.](image)

3.3. Working Flow
The working procedure of the system can be divided into three phase, preparing work, field work and data processing stage. The working flow is shown in figure 4. Where RP is abbreviation of the reference points, and MP is abbreviation of the monitoring points.
Preparing Work

Field work

Data processing

Reference points
Datum points
Grid net
Monitoring points

Survey
Monitoring Videos

Coor of RP in spatical reference
Transformation model
Coor of RP in image coordinate system
Coor of MP

Center detection
Edge detection

The displacement of the points

Figure 4. Working flow of the system.

Take monitoring dot 1 as an example, the coordinate list is \((x_0, y_0); (x_1, y_1); \cdots; (x_n, y_n)\), and the displacements in different directions then summarized as \([\Delta x_1, \Delta y_1); (\Delta x_2, \Delta y_2); \cdots; (\Delta x_{n-1}, \Delta y_{n-1})\], and the change amount and cumulative change amount of the current period are obtained. Based on those data, deformation vector diagram could be drawn and deformation trend can be analyzed.

3.4. Verify Examination

For the validation of the proposed system, images from two adjacent periods need to be prepared and be processed following the procedure in figure 3. Different displacements are generated by adopting different edge filters. On the other side, all the coordinates of the testing points are measured by the high precision traditional measuring device, such as the total station (the nominal accuracy is better than 0.5″), and the result will be used as the standard value. By comparing the mean square error, the optimal filter will be chosen.

4. Key Challenges and Conclusion

Remote sense has become ubiquitous in civil application. The method proposed in this paper is a typical application of remote sense in geomantic hazard monitoring. It offers a possibility of semi- or automatic monitoring with low labor intensity and cost. Despite all the advantages, there are still some challenges, list as follows.

1) The quality of the monitoring system highly depends on image processing algorithms, and
2) Fixed measuring points should be buried, and they may be destroyed if the strong deformation happened, and
3) Even we developed the observation by setting up a grid, the observation data is a small part of the monitoring area that cannot reflect the deformation characteristics of the whole area, and
4) The cost and labor for the duration monitoring work are reduced, but there are initial investments and high labor intensity to set up the monitoring system.
As future work, we plan to improve the results obtained by getting the DEM of the research area and implement the process in a UAV platform.

Acknowledgement
The authors would be grateful for the financial support provided by Science projects from Chongqing Science and Technology Bureau (Grant No. cstc2019jscx-msxmX0318), the Science and Technology Research Project of Chongqing Municipal Education Commission (Grant No. KJQN201904307), the Science Project of Chongqing Jianzhu College (Grant No. JG-KJ-202002) and the science project from Chongqing China State Hailong Liangjiang construction technology company limited (2020CQHL003).

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