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THE RESEARCH AND APPLICATION OF LANDSLIDE SURFACE CRACK MONITORING METHOD BASED ON LASER RANGING MODE

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ABSTRACT

The paper proposes a non-contact landslide surface crack monitoring method based on laser ranging principle. This intelligent monitoring method realizes real-time landslide monitoring with low cost, and this design will solve these technical problems such as vulnerable, disturbed and measurement errors, which exist in electromagnetic and contact-type landslide fissure monitors, meanwhile it also solve problems such as high cost, installation complexity and low real-time in GPS or total station. This intelligent monitoring method uses GPRS to transmit data， and these data will be deposited in monitoring center database. It has been carried out field test on landslide in Bazhong city, Sichuan province, China. With the great effect in landslide monitoring, this system will provide technical support in geological disaster prevention and reduction.

Keywords: Landslide surface crack, Laser ranging, GPRS, Real-time monitoring, Disaster prevention and reduction.

1. INTRODUCTION

China is a country with many geological disasters, which have a wide distribution, high frequency and high impact, and these disasters seriously threaten life and property. Due to the speciality and emergency of geological disasters, it will cause great damage to the natural environment, people's life and property and construction [1]. The surface crack is one of the components of the landslide, and the landslide crack is a kind of the surface crack. When the sliding force is greater than the anti-sliding force caused by natural or man-made factors, the slope will be unstable, then the ground cracks will be formed between the sliding body and the stable body, which is the cause of landslide crack. The surface cracks of landslide are widely found in all kinds of landslides, and it is a direct reflection of the highly fluctuation zone in the landslide.

Cracks observation is a common method for the prevention of geological disasters, so it is widely used in landslide monitoring [2]. At present, the crack monitoring apparatus is mostly based on electromagnetic and contact surface expansion, these methods are simple and cheap, but they have some shortcomings, firstly the wire above the ground is only about 0.5 meters, people and livestock are easily tripped, so the monitoring equipment is extremely easy to damage. Secondly there will be a considerable measurement error because of its tension and its weight. Thirdly the falling tree branches and other crops will interfere measurement results. Meanwhile, nowadays non-contact measurement method is used to monitor the surface cracks of the landslide, such as GPS, total station and so on, but there are several problems such as high cost, installation complexity and low real-time, so it will brings negative effects on large-scale promotion and application in landslide monitoring.

The paper proposes a non-contact landslide surface crack monitoring method based on laser ranging principle. This intelligent monitoring method realizes real-time landslide monitoring with low cost, and this method will solve these technical problems such as vulnerable, disturbed and measurement errors, which exist in electromagnetic and contact-type landslide fissure monitors, meanwhile it also solve problems such as high cost, installation complexity and low real-time in GPS or total station. The stability and real-time performance of the system can be ensured by the field application [3].

2. DESIGH OF MONITORING SYSTEM

The non-contact monitoring system consists of field data collection and indoor data receiving center (including GPRS receiving module). The design drawing is shown as Figure 1.

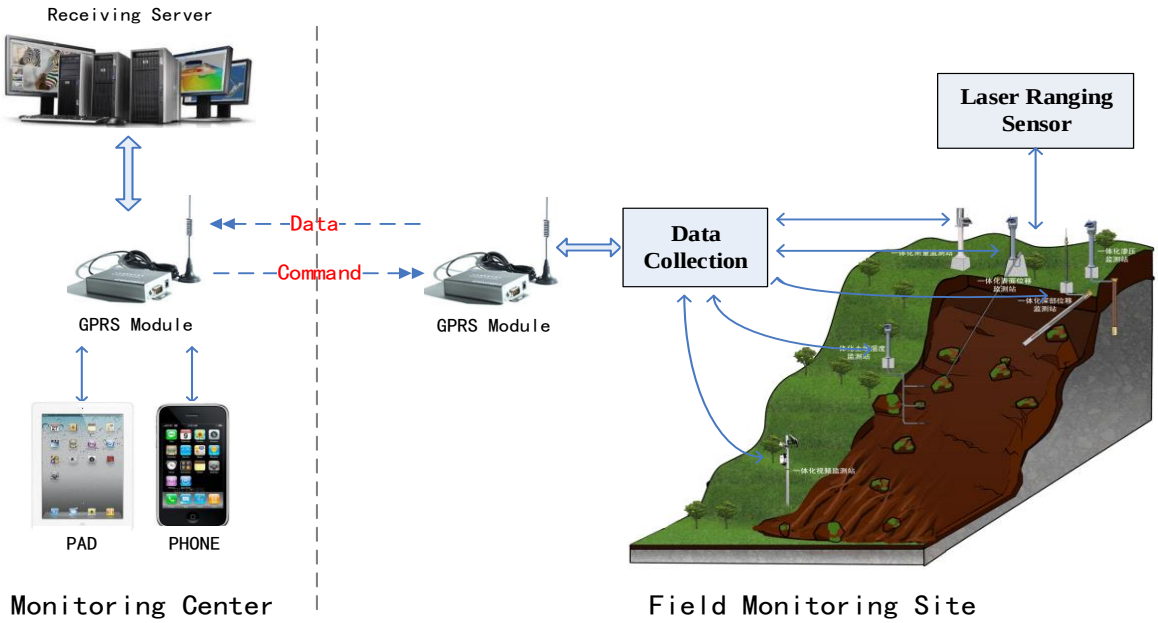

Figure 1. The Design Drawing of Monitoring System

As shown in Figure 1, firstly monitoring center indoor sends data acquisition command to the landslide monitoring site through the GPRS module, when data collection receive the acquisition command, laser ranging sensor will be started by command parsing. Laser beam which is emitted from laser range sensor reflects from target on the other side, the data collector gets data and sent data to the IP port of monitoring center, then the data will be saved in receiving server after verified.

In the field, field monitoring site consists of laser ranging sensor, data collector, GPRS module and monitoring target. Laser ranging sensor, data collector and GPRS module are fixed in landslide crack stable side, monitoring target is fixed in landslide crack instable side. The working layout chart of field monitoring site is shown as figure 2.

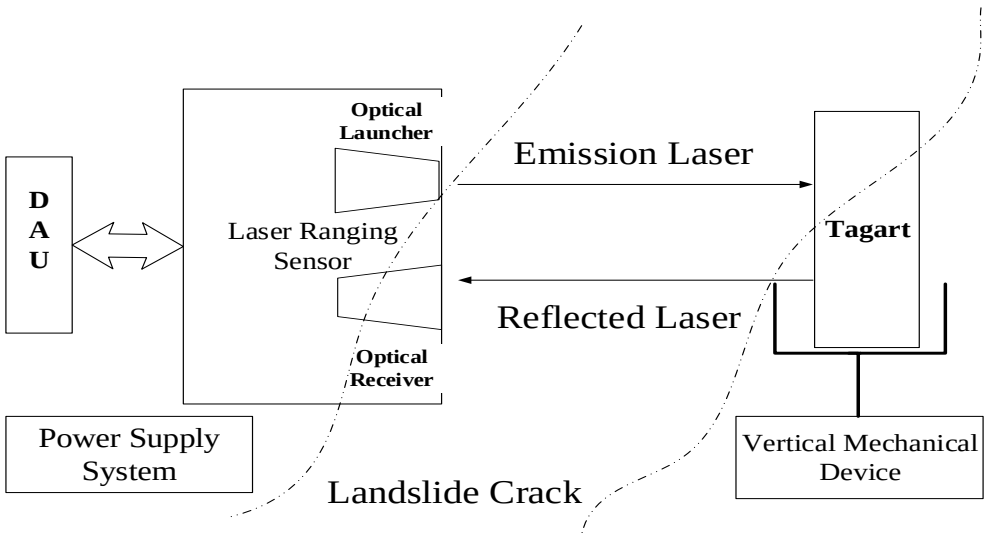

Figure 2. The working layout chart of field monitoring site

3. SYSTEM MEASUREMENT PRINCIPLE

The main measurement principle of landslide surface crack monitoring method is non-contact. Using the high precision of the laser ranging sensor, this system can measure the width of landslide crack by calculate the cycle time of pulsed light. Then there is the working principle in detail, firstly the multi-emitter laser diode emits laser pulse towards the target, the laser beams scatter in every direction after target reflection, part of scattering light will return back to receiver, and the light will be imaged to avalanche photodiode after received by optical system. The avalanche photodiode is an optical sensor with an internal amplification function, so it can detect very weak optical signal, then the cycle time will be recorded and processed, so the target distance can be measured. The photos of hardware debugging are shown in figure 3.

Figure 3. The Photos of Hardware Debugging

Among them, in the use of laser ranging sensor to detect the landslide surface cracks, the general target and sensor distance is close, the laser propagation speed is very fast, the need to accurately measure the time difference between the launch and reflection, can be converted into the actual distance. The formula is shown in formula 1:

$$D=\frac{c \bullet t}{2} \tag{1}$$

In formula 1, D is the distance between observation point A to B, is the propagation velocity of light in the atmosphere, t is the light propagation time between A to B.

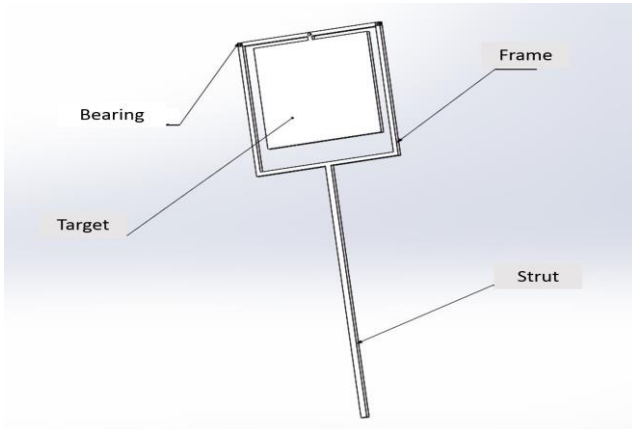

Figure 4. The Target Design Diagram

4. KEY TECHNOLOGY RESEARCH

The key technology of the monitoring system in this paper is mainly reflected in the design process of the target reflecting board and the automatic monitoring technology of geological disaster.

(l) The design process of the target reflecting board. Because of the characteristics of the landslide surface cracks, the monitoring target of the strong fluctuation side of the landslide is deflected by the tilt of the surface, which leads to the data error. As a key problem, this paper designs a vertical mechanical device to ensure the vertical of target reflection plate, thus the device ensure the accuracy and stability of the measured data. The target design diagram is shown in figure 4.

(2) Research on automatic monitoring technology of geological disaster. This real-time monitoring method uses Internet of things technology and GPRS communication technology, and it based on μC/OS-Ⅱ embedded operating system, realizing the real-time online landslide crack monitoring. μC/OS-Ⅱ is a preemptive multi task real-time operating system based on priority, including real-time kernel, task management, time management, inter task communication and synchronization (semaphore, mailbox, message queue) and memory management functions. μC/O-Ⅱis a complete, portability, preemptive and real-time multi task kernel, and it is wildly used in embedded systems arena for its portability [4].

According to the demand and characteristic of landslide crack monitoring, this paper divides total task into 4 subtasks. Through distribution and calling of μC/O-Ⅱ system, the monitoring task will be complete with high efficiency and low cost. Subtasks function is shown in table 1.

Table 1. Subtasks Function of μC/OS-Ⅱ

No.	Subtasks	Function
1	Data acquisition	Multi-channel and real-time acquisition
2	Data package and sending	GPRS & Beidou satellite
3	Command analysis	Start to wake up the system
4	Battery Checker	Electric quantity detection

Monitoring center platform software use C++ language to programme, software user interface use C# language to programme in Microsoft .NET Framework 3.5 version, and backstage provides support for Microsoft SQL Server 2008R[5]. The software has functions of setting up monitoring points, database enquiry, data export, curve drawing, graphic zoom and so on, the process and function of software is shown in figure 5, and the software interface is shown in figure 6.

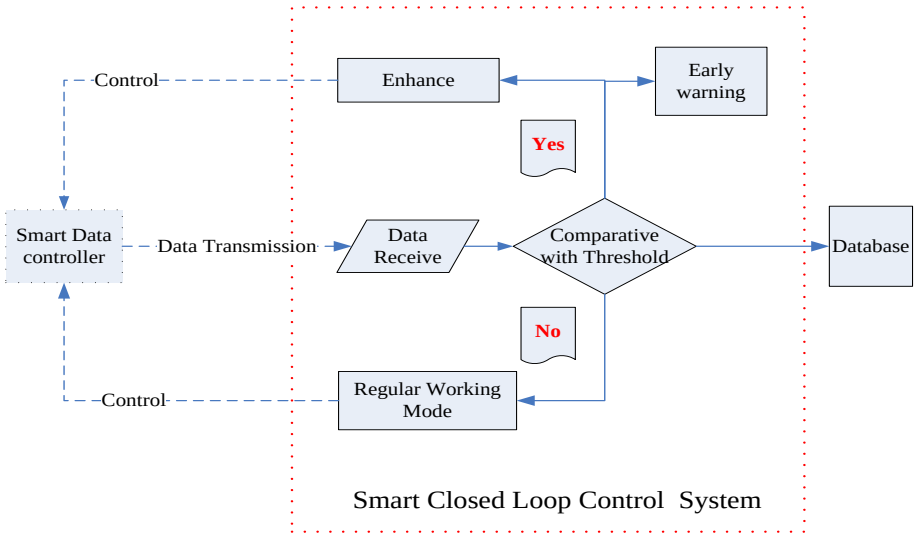

Figure 5. The Process and Function of Software

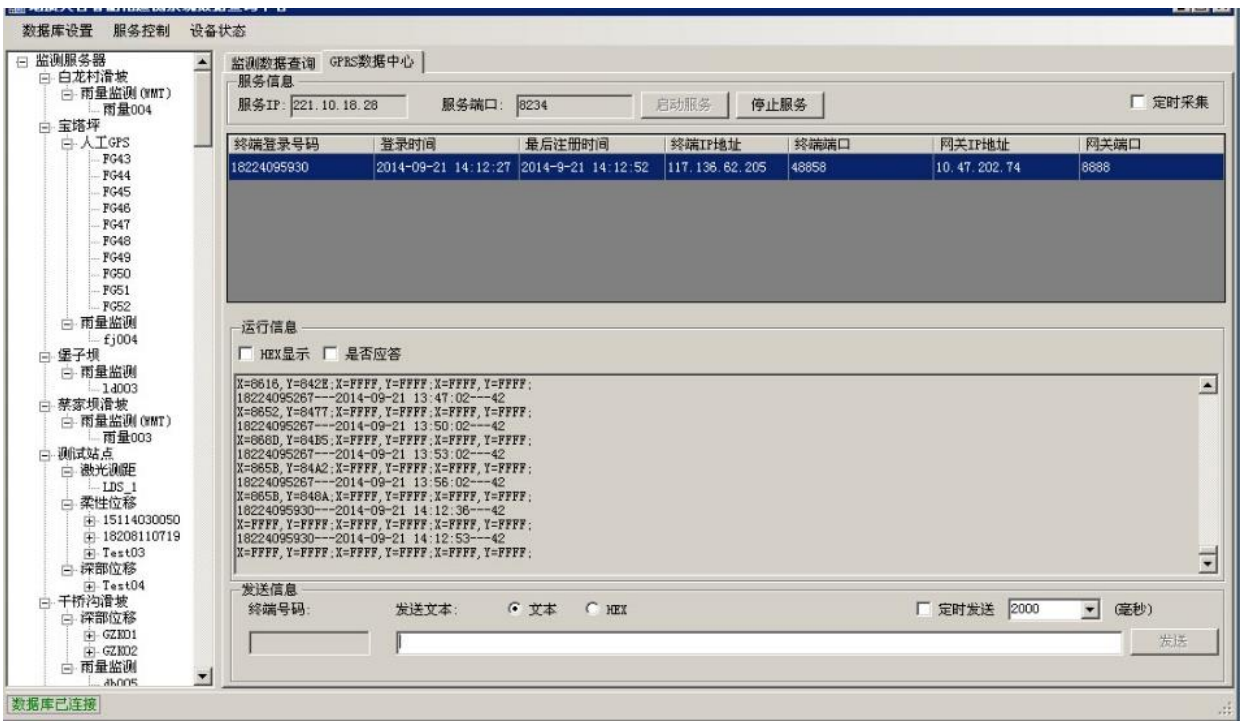

Figure 6. Software Interface Diagram

5. FIELD APPLICATION AND DEMONSTRATION

Bazhong City is located in the territory of Sichuan province in southwest China, which is the key area of the Ba River, so it has an important strategic position. Niu machang landslide is located in group 2, Longjiang village, Fengyi town, Nanjiang county, Bazhong city, and its position is 31 degrees 52 minutes 24.40 seconds North latitude and 106 degrees 36 minutes 33.33 seconds East longitude, and this landslide belongs to typical slow-down bedding rock landslide. The slope structure is a dip slope, and the nature of the slope is a bedrock landslide. The landslide's volume reaches 12000000 m3, which belongs to large scale landslide. A large number of surface cracks occurs in the rear edge of the landslide, the width of some cracks even reach more than 8m, and this disaster will seriously threat the safety of the residents under the village landslide, even lead to suspend Shilong River Hydropower station under this landslide. The pictures of the landslide and its crack are shown in figure 7.

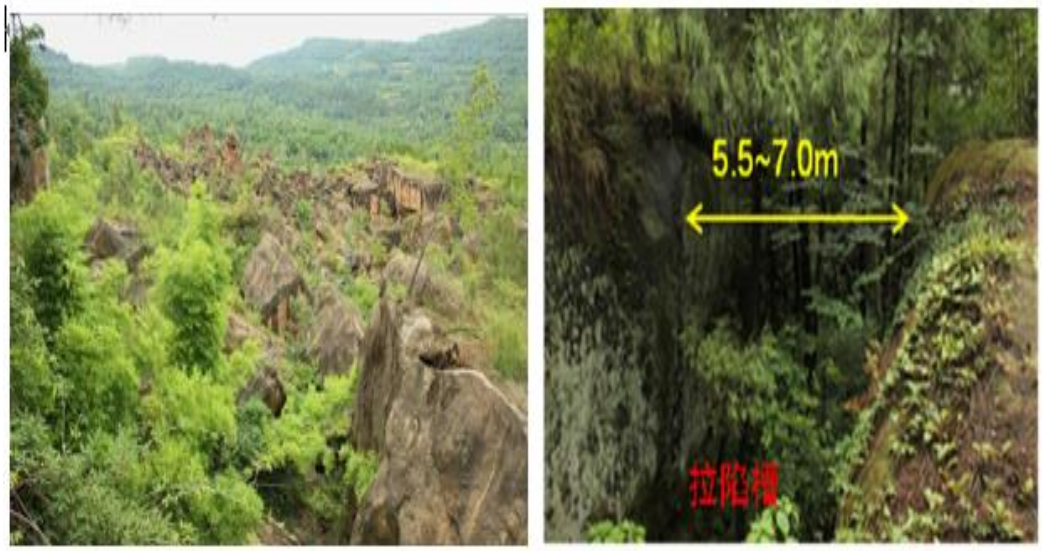

Figure 7. Pictures of This Landslide and Its Crack

For this type of landslide which rear edge has the obvious cracks, the monitoring method in this paper particularly suitable for monitoring this type of landslide, and this monitoring method will provide effective and reliable data for landslide monitoring and stability analysis. This monitoring system has installed on 2 rear cracks in trailing edge in early 2015. According to section 3.2, the laser ranging sensor and transmission terminal are installed on the stable bedrock, and the monitoring target is installed on the other side. Crack data is transmitted to the monitoring center in real-time by GPRS, and the power supply system uses solar energy to charge and uses lithium battery to supply, and these methods will ensure the long-term and stable operation of the system[6]. The system has started to work from the beginning of February 2015 to nowadays, and the system has been monitored for almost half a year, all the data has been entered into the monitoring center database. The typical data of No.1 is shown in table 2, and the changes in the value of the histogram is shown in Figure 8.

Table 2. The Typical Data of No.1

Minitoring Site No.1		
Date	Crack Width (m)	Change Value (m)
2015/2/5	5.70	0.00
2015/3/15	5.72	0.02
2015/4/6	5.75	0.05
2015/5/8	5.98	0.28
2015/5/9	5.95	0.25
2015/5/10	5.97	0.27
2015/6/22	5.88	0.18
2015/7/12	5.90	0.20
2015/7/13	5.99	0.19
2015/7/24	6.05	0.35

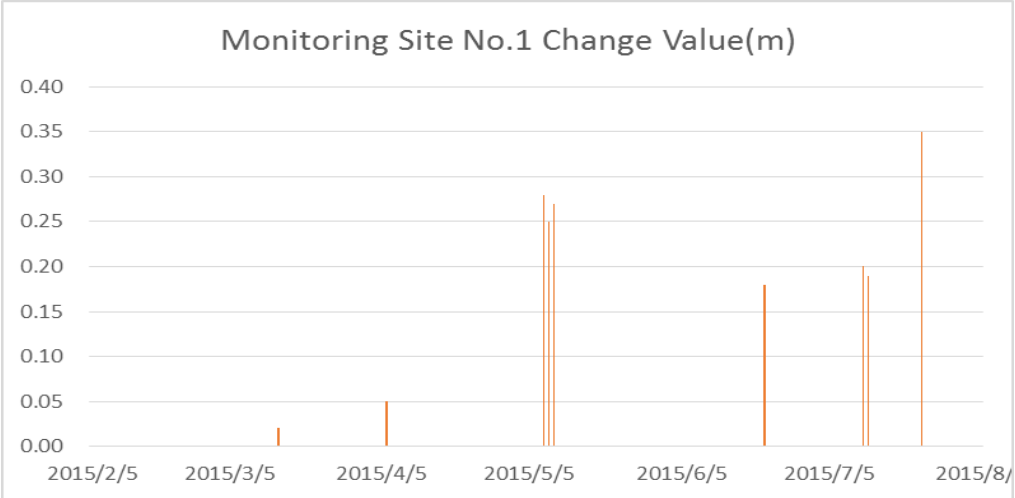

Figure 8. No.1 Change Value Diagram

6. CONCLUSIONS

(l) In this paper, the monitoring method adopts non-contact laser ranging sensor for the surface crack monitoring. This system has been applied in Indoor measurement(the system has been tested in Sichuan Provincial Bureau of test and measurement, China) and field application demonstration for long time, which can ensure the stability of the data and the stability of the monitoring system, and providing real data for the geological disaster prevention and reduction.

(2) Through the research of key technologies, the design process of monitoring target reflecting plate is solved,, and the data automatic monitoring is also realized. According to these methods, the data will be true and reliable. Meanwhile, the method uses the embedded operating system of C/OS- II and GPRS communication protocol to realize the automatic monitoring of the landslide cracks, basically reaching the demand of the future monitoring technology.

(3) For this type of landslide which has bedding rock and shelving angle, the monitoring method in this paper particularly suitable for monitoring this type of landslide, and by comparing with other monitoring instruments (such as deep displacement monitoring, GPS monitoring), it will be more realistic of real-time state for landslide, so this system will provide technical support in geological disaster prevention and reduction.

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