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Design and Implementation of Landslide Data Acquisition Equipment Based on Multi-Sensor

Yongli Hu

Hunan University of Science and Technology, Xiangtan, China
572295090@qq.com

Abstract: *At present, there are many methods and means of landslide monitoring, but in practical application, the monitoring effect is not ideal. The natural environment and causes of landslides in different types and locations are different. Traditional landslide data acquisition equipment is usually specially designed for a certain place, with single function, strong specificity, low universality and poor adaptability. Therefore, it is necessary to study and design a multi-parameter automatic monitoring data acquisition equipment for landslide and realize the acquisition of various landslide parameters. To sum up, based on the real-time monitoring and early warning platform for landslides with multi-sensor information collection, a monitoring method consisting of sensors, instruments and controllers is designed. This versatile landslide data acquisition equipment can be flexibly configured according to the actual situation of monitoring slopes, so as to realize real-time data acquisition of various types of landslides and provide timely and reliable data basis for landslide monitoring and early warning.*

Keywords: *sensor, controller, data acquisition, landslide monitoring*

1. Introduction

Landslide monitoring is mainly to monitor all kinds of characteristic phenomena in the process of landslide development, which can be summarized into three aspects: landslide deformation monitoring, landslide deformation damage related factors monitoring and landslide induced factors monitoring. The main monitoring methods include surface displacement monitoring, deep displacement monitoring, rainfall monitoring, groundwater level monitoring, etc.[1,2]. The monitoring methods range from manual monitoring to real-time automatic monitoring, and the monitoring elements range from single factor to multiple factors[3,4]. Landslide monitoring and management information systems corresponding to landslide monitoring methods have also been widely studied. These landslide information systems have the functions of monitoring data transmission, data storage, data processing, monitoring and early warning model realization[5,6], and there are also many management systems in real-time automatic monitoring of landslides, such as Liu Chao et al.[7], using GPS/GPRS for remote landslide monitoring, Cheng Buming et al.[8], through wireless sensor networks[9, 11]. At present, there are some monitoring and early warning systems for landslides, but there are still some places that need to be improved. The landslide data acquisition equipment based on multi-sensors designed in this paper collects a variety of mountain parameter information, which provides a data basis for landslide monitoring and early warning.

2. Design Philosophy

Some traditional landslide data collection devices mostly use a single sensor to analyze the landslide with a single parameter, and the collection and analysis of landslide monitoring elements are relatively one-sided. Moreover, the working environment of the equipment is bad, and the single data upload is easily disturbed, which leads to the unsuccessful data upload. Moreover, when the sensor collects data, there may be environmental impact or interference, and the original data is not preprocessed, which affects the effectiveness and reliability of the data to a certain extent.

Because geological disasters are sudden, different disasters will occur in different geographical locations, so there must be certain standards in the selection of sensors and the correct position should be set in the use of sensors. The main contents laid out on the sensor are as follows: in the monitoring of landslide, it is necessary to find out the factors leading to landslide and the situation of surface movement, so there must be relevant monitoring on the surface and underground, so the cracks in the

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back wall and the inclination of the front edge of landslide are mainly monitored on the surface; Underground monitoring mainly includes deep displacement, moisture content of underground soil, groundwater level and earth pressure. In the underground monitoring project, the sensor must be buried below the main sliding surface of landslide in the deep displacement monitoring.

For high-risk landslide or high slope, the focus is on its deformation monitoring, that is, several displacement measuring points are arranged on the surface of the monitored object, and at the same time, a set of deep displacement monitoring instruments are arranged at different elevations to jointly monitor the displacement, deformation or inclination of the slope or landslide and monitor its stability in real time. For slopes or landslides in high groundwater areas, observation points of groundwater level can be added. Considering the inducing effect of rainfall on geological disasters, observation points of rainfall need to be arranged. At present, the layout of some landslide data acquisition equipment is shown in the following Figure 1:

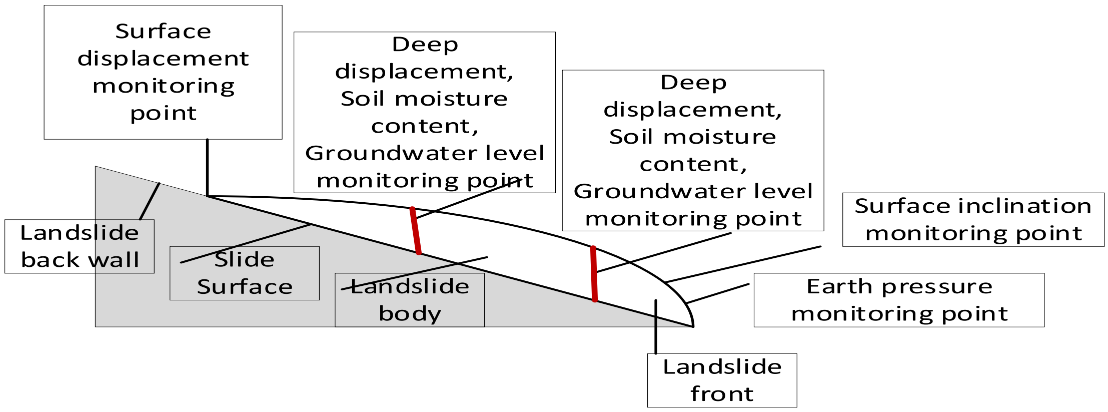

Figure 1: Layout of landslide data acquisition equipment

Aiming at the problems of traditional landslide monitoring scheme, such as single collection variable, no early warning and prediction, only monitoring surface characteristics and so on. Compared with the traditional landslide data acquisition equipment, the front-end equipment designed in this paper can obtain landslide parameters very comprehensively by using multiple types of sensors, which can provide more abundant data for landslide trend early warning analysis and improve the accuracy of forecasting and early warning to a certain extent; In addition, the controller preprocesses the original data from the source to improve the reliability of the data; Finally, the collected data is uploaded to the cloud center server through GPRS wireless communication, which ensures the reliable transmission of the data and the real-time performance of the data to a certain extent. The main work of this design lies in the collection of multi-sensor monitoring elements, data preprocessing, data calculation and data transmission, so as to ensure the comprehensiveness, accuracy and reliability of data as much as possible. The structure of landslide monitoring data acquisition equipment designed in this paper is shown in the following Figure 2:

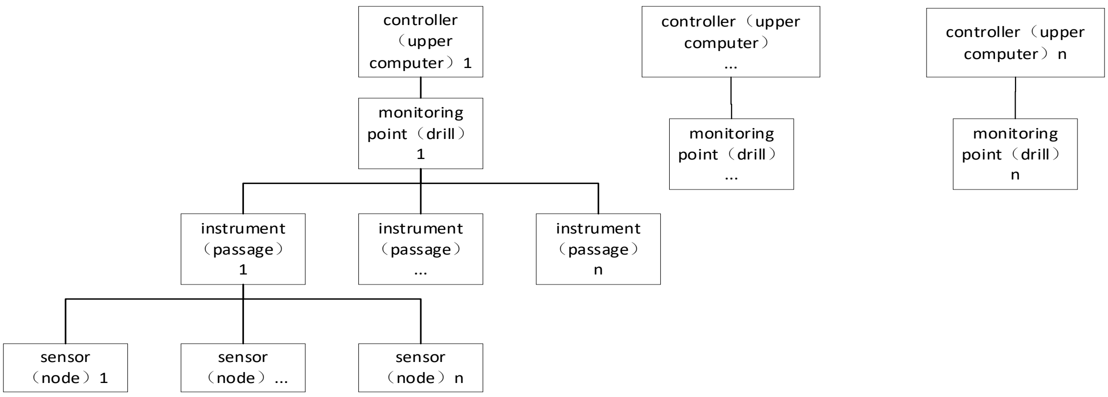

Figure 2: Structural framework of data acquisition equipment in this paper

According to the actual needs of landslide monitoring data, the following types of sensors are needed: gravity acceleration sensor, surface displacement sensor, rainfall sensor, water level sensor, water pressure sensor, earth pressure sensor, inclination sensor, cable displacement sensor and cable tension sensor.

3. Sensors, Instruments and Controllers

In this paper, various types of sensors are used to collect slope data. In order to better control and collect different types of sensor data, a sensor management mode is given, as shown in Figure 3:

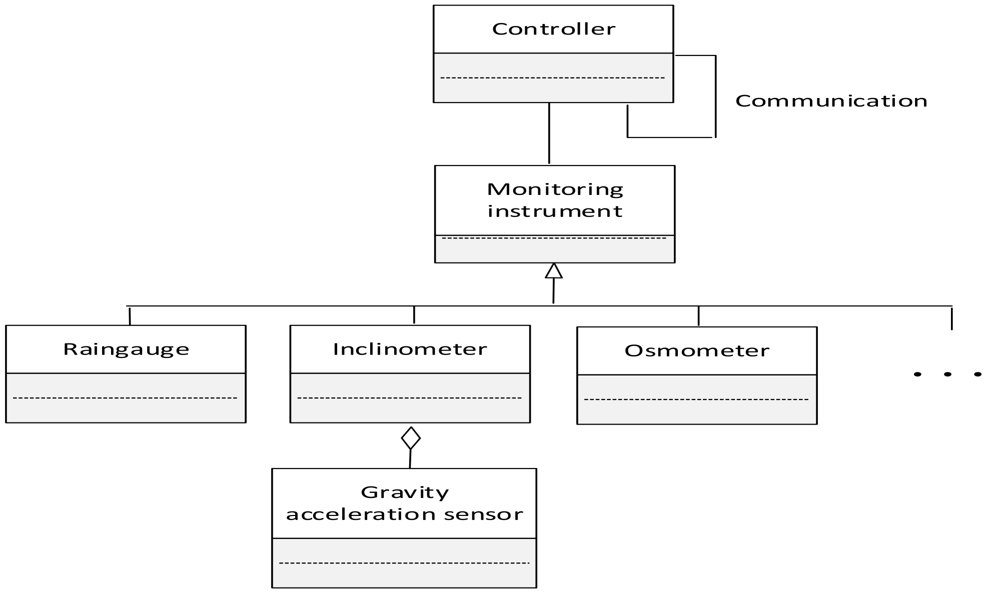

Figure 3: Relationship diagram between controller and sensor position

Observing Figure 3, we can see that "instrument" is added between the sensor and the controller. In the slope automatic monitoring platform, a monitoring point can be equipped with various types of sensors, and it can also be equipped with various sensors of the same type. For example, a borehole can be drilled with multiple gravity acceleration sensors (deep displacement monitoring), rainfall sensor monitoring (rainfall monitoring), water level sensor monitoring (water level monitoring) and so on. In order to facilitate the control and management of different types of sensors, such as setting different monitoring modes for different types of sensors. It is stipulated here that the same type of sensors at the same monitoring point are connected to the controller by the same type of channel, that is, all sensors connected to the controller by the same channel are called an instrument, that is, the instrument refers to the sensor set composed of 1-N sensors of the same type connected to the controller through a channel. There are 1-N types of channels, and the channel types are divided according to the data types collected by sensors, such as gravity acceleration, rainfall, water pressure, water level, etc. There can also be multiple channels of the same type, such as 3×A, 2×B and 1×C, indicating that the controller has three A-type channels, two B-type channels and one C-type channel.

After power-on reset, the controller allows users to set the number of instrument channels to be opened and the opening time of each channel. After the setting is confirmed, the controller starts to run. During the operation, the controller will record the collected monitoring parameters, including the currently opened channels and the remaining time before each channel is closed. In addition, the user platform can set the operating parameters of the controller conveniently, without manual setting in person. This design not only enables all kinds of users to know the running state of the controller, but also facilitates remote control. To sum up, the introduction of multi-channel instrument controller can realize the classified management of sensors and the monitoring methods with different granularity, and ensure the feasibility of real-time monitoring.

4. Controller Design

The controller is a device that controls all kinds of instruments to collect monitoring elements. It also has the functions of data calculation, data storage and data transmission to the cloud center. The controller can control different types of monitoring elements instruments, and can also control multiple instruments of the same type, and only one controller is needed for a worksite. By connecting various sensors, the controller collects many parameters that affect the slope, such as deep displacement,

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rainfall, soil pressure, pore water pressure and so on. The structure of the controller is shown in Figure 4:

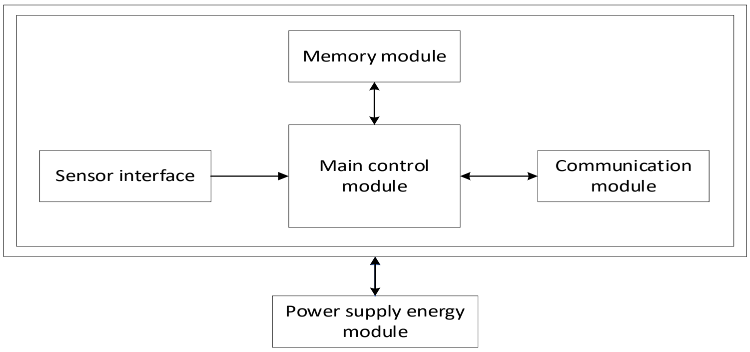

Figure 4: Controller structure

As can be seen from Figure 4, the core part of the controller consists of sensor interface module, storage module, communication module and data processing module. Sensor interface module, that is, various types of channels of the controller, collects monitoring data collected by various types of sensors by controlling the sensors. The storage module is used to store the monitoring data for a period of time. In case of special circumstances, such as equipment failure or slope in a certain period, the safety and integrity of the data can be guaranteed. Data storage can be divided into two parts: one part is used to store device parameters, such as IP address, port number, acquisition channel and data upload time interval. The other part can store the monitoring data and equipment status collected by various sensors. The communication module adopts GPRS wireless communication, which is responsible for data interaction between the controller and the server, receiving and processing messages from the cloud platform, sending monitoring data encapsulated into messages and feeding back messages to the cloud platform. The data processing module is responsible for the pretreatment and calculation of various monitoring data.

In addition to the core part, there is also a power module, which is the basis for the normal operation of the equipment. The power module is mainly composed of storage batteries, supplemented by solar charging, and supplies power to other modules to ensure the normal operation of the equipment as a whole. Moreover, the node can work for a long time without worrying about the exhaustion of battery power, which can save a lot of manpower and material resources. The overall working flow of slope data acquisition equipment is shown in Figure 5:

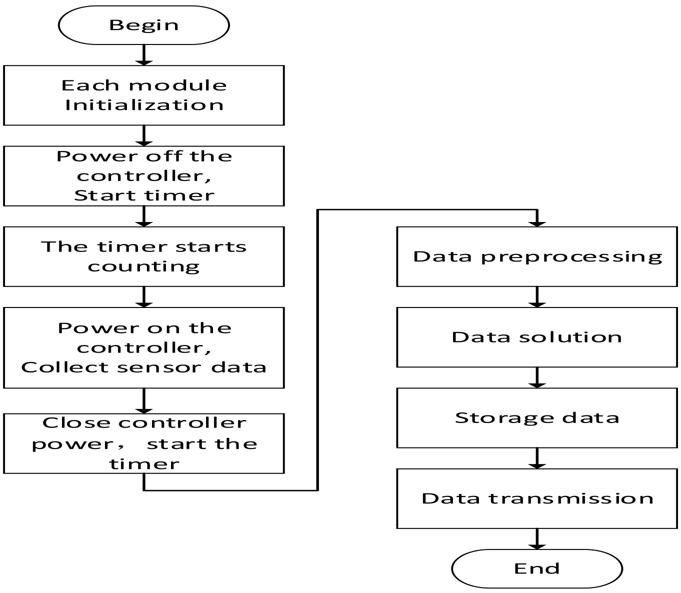

Figure 5: Flow chart of controller operation

After the initialization of each module, considering that the controller is in a field environment and it is difficult to supply power, its power consumption should be kept as small as possible, and in combination with the working characteristics that sensors do not need to collect parameter information at all times, the power supply of the controller is turned off at ordinary times, and when data need to be collected, the power supply of the controller is turned on. After data of various types of sensors are collected, they are stored and backed up locally, and then the data is preprocessed, and then the data of various types of parameters are calculated. After the data processing is completed, the data is finally wirelessly transmitted to the central server through GPRS. The main functions of the controller include data acquisition, data processing, data transmission and status reporting. The functional module diagram of the controller is shown in Figure 6 below:

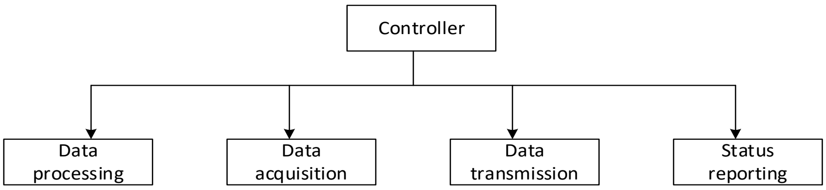

Figure 6: Controller function module

Data acquisition: Considering that there are many kinds of sensors used in field monitoring, and the interfaces of various types of sensors are inconsistent, the controller needs corresponding sensor interfaces to realize the communication between the controller's main control module and the sensors, so that the data collected by the sensors can reach the main control module.

Data processing: data processing is one of the core functions of the controller. First, it is data storage, which ensures the local storage and backup of data and prevents the original data from being obtained during data transmission or when the equipment fails. Due to environmental influence or interference, it will have a certain impact on the later data calculation. Therefore, it is necessary to preprocess the original data and then calculate the data of various types of monitoring data to reduce the calculation task of the cloud center server. Data transmission: After data collection and processing, the data needs to be sent to the server. Status reporting: The user platform can view the running status of field monitoring equipment. So that managers can complete remote access, monitoring and maintenance of field devices through the user platform.

5. Conclusions

The multi-sensor automatic landslide monitoring platform has been put into production and application by Guizhou Traffic Planning, Survey and Design Institute Joint-stock Research Company since January 2018. The cumulative number of landslides monitored by the platform has exceeded 100, and more than 10 landslides have been monitored in real time. The platform is running normally.

The relative dip angle measured by inclinometer increased steadily at an angle of 45 from the minimum value of 0.01 on January 18th, 2023. By the beginning of February, the growth trend changed, with an increase range of 90. The relative dip angle increased rapidly to 2.6 in a few days, and then remained between 2.6 and 2.7. Until the end of February, the local staff took measures to control the slope, the relative dip angle decreased to about 2.3 and remained stable for a long time. There is a big difference in the incremental displacement of the stay wire, the displacement value increased rapidly from May 2022 to September 2022, and stabilized after the slope was treated in October.

To sum up, the monitoring data of different monitoring equipment can reflect the process from slope deformation to stabilization after slope treatment, which shows that the local residents can take landslide treatment measures or transfer residents and property in advance through multi-type monitoring of slopes and early warning of landslide accidents, thus avoiding casualties and a large number of property losses.

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