Design of Remote Acquisition System for Debris Flow Data Based on STM32

Li Li, Lin Xue*, Xiaoqi Zhang, Peifeng Ji, Pengxiao Teng and Hesong Huang

ABSTRACT

Manual monitoring of debris flow is now widely used with the limitations of time-consuming, hardworking and poor reliability. To avoid these shortcomings, a remote automatic debris flow monitoring system based on STM32 is proposed. Adopting modular design, the system takes STM32 as the control core, uses AD8275 to adjust the acquisition signal, and chooses the high precision A/D converter ADS1256 to convert analog to 24bit digital signal which will be transmitted to remote control terminal via the 3G wireless communication network. Finally, the UM220 GPS module is used to correct time and monitor multiple network devices. Test result shows that the system, with high stability and a strong popularization value can achieve sampling accuracy of 0.1%.

INTRODUCTION

China is one of the countries that frequently occurs serious debris flow disasters. In recent years, frequent mudslides, especially in southwestern areas such as Sichuan and Yunnan, have caused heavy losses of property damage and casualties [1-3]. The research on debris flow disasters began in the middle of the 20th Century, but the factors of debris flow occurrence is so complex that its formation mechanism is now still in research by relevant research institutions at home and abroad. Debris flow area monitoring is the major method to study the formation of debris flow, as well as an important measure to prevent debris flow disasters [4-6]. Traditional

---

*Li Li, Lin Xue*, Hesong Huang. Shandong University of Science and Technology, Qingdao, China
Xiaoqi Zhang. Shandong College of Information Technology, Weifang, China
Peifeng Ji, Pengxiao Teng. Key Laboratory of Noise and Vibration Research, Chinese Academy of Sciences, Beijing, China
mudslide monitoring usually sets simple monitoring points in the field, and mainly by manual monitoring. Because this method is relatively simple and the monitoring equipment technology is backward, monitoring work is difficult to implement when encountering the harsh environment [7]. Therefore, it is of great significance to study and design a remote automatic monitoring system of debris flow with high real-time and good accuracy.

The remote automatic monitoring system of debris flow takes STM32 as the control core, selects 24bit high-precision chip ADS1256 to perform analog to digital conversion of sampled signals, and transmits the real-time monitoring data to remote monitoring terminal by 3G wireless communication. Meanwhile, the remote automatic monitoring system of debris flow uses GPS module to synchronously calibrate the time, so the signal acquisition accuracy of the system has been improved. In this paper, the whole design process is considered from two aspects: hardware design and software design. With the system measurement accuracy being better than ±0.1%, it is a great improvement on the sampling accuracy and the stability of the system.

SYSTEM OVERVIEW AND HARDWARE STRUCTURE DESIGN

System Overview

The overall architecture of the debris flow remote automatic monitoring system designed in this paper is shown in Figure 1. The system consists of two parts: the data acquisition terminals and the background monitoring terminal.

In the data acquisition terminal, the capacitive infrasound sensor transmits the collected debris flow infrasound signal which is processed by STM32 to the network server. If the data acquisition terminal has detected network interrupt during data transmission, the data will be automatically stored in the local SD card and the system will reconnect to the network constantly. Once the network communication is restored, the data acquisition terminal will send the temporarily stored data from the SD card to the background monitoring terminal.

The background monitoring terminal using the monitoring platform can display the infrasound variation of debris flow in real time. And by logging on the network and selecting data acquisition terminal in the field, the staff can enter the wave form display interface. According to the GPS latitude and longitude information, the staff can also check the occurrence of debris flow in different monitoring areas.

![Figure 1. The overall structure diagram of debris flow monitoring system.](image)
Hardware Design of Data Acquisition Terminal

According to the function requirements, the data acquisition terminal of the debris flow monitoring system takes the STM32F103ZET6 as the core in the hardware design, and extends the ADS1256 analog-to-digital conversion, Micro SD card storage, 3G network communication module, GPS positioning module, W5500 Ethernet module, etc. The hardware structure block diagram is shown in Figure 2.

SIGNAL CONDITIONING CIRCUIT AND SAMPLING CIRCUIT

The core of the data acquisition terminal is a signal sampling circuit. In the sampling circuit, the data acquisition terminal uses the ISD2016 infrasound sensor developed by the Acoustics Institute of the Chinese Academy of Sciences to collect the infrasound signal of the debris flow. This sensor converts the infrasound wave collected into voltage signal with an amplitude not exceeding ±10V and transmits to A/D conversion module.

According to sampling rate and accuracy requirements, this paper selects the micro-power chip ADS1256 manufactured by TI company as the core of A/D conversion circuit. The programmable filter allows the user to optimize between a resolution of up to 23 bits noise-free and a data rate of up to 30k samples per second (SPS)[8-9]. In this design, the ADS1256 works in unipolar input mode. Its first three channels are used, and a crystal with the frequency of 7.682MHz to provide the clock signal.

Since the ADS1256 can only input 0~5V voltage signals, it is necessary to convert the voltage signal whose amplitude is no more than ±10V to 0~5V voltage signal through the conditioning circuit. This design uses AD8275 from Analog Devices as the signal conditioning chip. With features of the low offset and low offset drift and the fast settling time, AD8275 is suitable for a variety of data acquisition applications where accurate and quick capture is required. Figure 3 shows the peripheral circuit of the AD8275.

Figure 2. The design diagram of hardware structure.
The ±10V voltage signal output by the external sensor passes through the conditioning circuit to obtain a voltage signal of +0.048V~+4.048V, and after low-pass filtering, the voltage signal inputs the ADS1256 chip. The peripheral circuit of the ADS1256 is shown in Figure 4. ADS1256 adopts SPI bus as the data transmission mode to transmit the sampled data to the processor.

**WIRELESS COMMUNICATION MODULE**

This design selects SIM5360 by SIMCOM Company as the 3G wireless network communication module of the data acquisition terminal. The 3G wireless network module, together with the GPS positioning module UM220III, can package the relevant information such as sampling time, latitude and longitude, date, sampling data and infrasound data into TCP/IP data packets and send them to the monitoring terminal by 3G wireless network.
WIRED NETWORK PORT COMMUNICATION

The communication mode of the data acquisition terminal is mainly to send data to the monitoring terminal through the 3G wireless network. But in order to facilitate the on-site debugging of the staff, the data acquisition terminal of the design also has an additional wired network port communication interface. The design uses W5500 to read data from the data acquisition terminal. W5500, which has 8 independent hardware sockets simultaneously, enables users to have the Internet connectively in their applications just by using the single chip in which TCP/IP stack, 10/100 Ethernet MAC and PHY embedded. Without the need of an additional PHY chip, the W5500 just needs to install the RJ45 interface HR91105A which has a network transformer to start working. The network communication interface is shown in Figure 5. W5500 connects to MCU through SPI bus, which can keep a communication rate of 80 MHz.

GPS SYNCHRONOUS CLOCK AND POSITIONING MODULE

The wireless data acquisition terminals mostly use three acquisition terminals to form a triangular array for data acquisition and they are mainly distributed in the field. Comparing with the three groups of data can get the final results. However, the delay of each collection terminal is inconsistent during the transmission process. Therefore, in order to obtain synchronous data, all data acquisition terminals need to use the same time standard [10]. Comparing with the 3G network timing, the design uses the domestic Beidou UM220III which has high sampling rate. GPS obtains the UTC time and corrects error by second pulse, getting the final system time whose relative error is less than 20ns.

THE SOFTWARE DESIGN OF DATA ACQUISITION TERMINAL

The workflow of the data acquisition terminal is shown in Figure 6. After power on, the system initializes the clock, serial port, interrupt, and data acquisition terminal modules. After the initialization is completed, the data acquisition terminal, according to the status of system network connection and the need of monitoring terminal, enters different working mode separately by the control command of communication protocol.

In the working mode 1, the monitoring terminal checks local stored data, as desired. The monitoring terminal sends query command to the data acquisition terminal. After received the instruction, the data acquisition terminal returns such information as the sampling time, the open status of each channel, and the connection condition of the 3G network. Otherwise, the data acquisition terminal performs working mode 2. If the system device runs normal and the 3G network connects successfully, data is remotely sent to the monitoring terminal. When the 3G network communication is failed, the network interrupt causing the data queue to
accumulate, the system will automatically save data instruction packet to the SD card in time. Meanwhile, the data acquisition terminal continuously detects the network interface and attempts to connect to the network. The system cycles in this mode to wait for new connection.

Figure 5. W5500 interface connection diagram.

![Diagram](image)

Figure 6. The work flow of data acquisition terminal.
A/D Sampling Subroutine

When the data acquisition terminal has obtained the running time of the system and the staff have started up the device, the terminal begins A/D sampling by the internal timer whose unit is μs. This design selects ADS1256 as the core of the data conversion circuit, and its sampling accuracy is 24 bits. The initialization of the ADS1256 chip will set 2000SPS sample output, so that its own sampling rate of up to 30KSPS is used for oversampling. And the average value is taken by multiple samples to improve the accuracy of the sampled data.

Different sampling frequencies are achieved by setting the sampling interval. The system enters the A/D sampling subroutine when the set sampling time is up.

Network Port Communication Subroutine

When the staff is debugging on the spot, the computer sending control command to the data acquisition terminal through the network port will trigger interrupt. The data acquisition system platform can provide the selection of system parameters, channels and sampling rates, the display of real-time data, and the reading, querying, playback, and export of historical data. It can also send different control command through the network port to set the working state of the device.

SYSTEM TEST

The system was tested in Dashu Town, Fengjie County, and Chongqing. Figure 7 is the on-site debugging diagram. Figure 8 shows a screenshot of part test data stored by the monitoring terminal while the input voltage is 4V. Every six-digit hexadecimal number represents a sampling voltage value. The channel samples input data continuously for 4 times to indicate that the work is normal and stable.

The voltage value stored in the monitoring terminal can be obtained from Equation 1:

\[
\frac{2 \times V_{REF}}{PGA \times (2^{23} - 1)} \times D
\]

\[ \text{(1)} \]

D is the decimal number coded for monitoring terminal storage. \( V_{REF} \) is the 2.5V reference voltage. PGA is the gain multiple of 1. The number 6664EF equals to the decimal number 6710511, \( 2 \times 2.5/ (223-1) \times 6710511=3.9997767 \); The number 6664C8 equals to the decimal number 6710472, \( 2 \times 2.5/ (223-1) \times 6710472=3.9997534 \). The error of the two groups of data is -0.0058% and -0.0062%. The result shows that the acquisition accuracy of the system is better than ±0.1%.
CONCLUSIONS

In this paper, a remote automatic monitoring system is designed for the problem of debris flow disaster. The system uses STM32 as the data acquisition terminal controller to process the infrasound sampling signal of the debris flow and communicate with the monitoring terminal through the 3G wireless network. And the system which can simultaneously sample signals from multiple regions is better than manual monitoring. Finally, the test proves that the system has high precision and good stability and achieves the anticipated result of the design. The measurement accuracy is better than ±0.1%. Moreover, providing solar panel and lead-acid battery power supply mode, the system is environment friendly and saves manpower and material resources.
REFERENCES

1. Z. Chen, R. Deng, and Z. Song. 2016. “Analysis of the Formation Mechanism and Blockage of Zhuzha Gully Debris Flow Disaster in Shimian of Sichuan on July 4th, 2013,” The Chinese Journal of Geological Hazard and Control, 27(3):42-46.
2. C. Ouyang, S. He, and C. Tang. 2015. “Numerical Analysis of Dynamics of Debris Flow over Erodible Beds in Wenchuan Earthquake-Induced Area,” Engineering Geology, 194:62-72.
3. C. Li, L. Wang, and K. Liao. 2014. “Study of Early Warning Mechanism of Debris Flow along Railway Lane in Mountainous Areas,” Chinese Journal of Rock Mechanics and Engineering, 33(2): 3811-3816.
4. J. Tu, Y. Yang, C. Li, A. He, and L. Li. 2015. “A Context-Adaptive and Energy-Efficient Wireless Sensor Network for Debris Flow Monitoring,” 2014 International Conference on Wireless Communication and Sensor Network, 157-162.
5. J. Chiu, C. Dow, C. Lin, J. Lin, and H. Hsieh. 2012. “A Watershed-Based Debris Flow early Warning System Using Sensor Web Enabling Techniques in Heterogeneous Environments,” IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 5(6):1729–1739.
6. K. H. Xu, D. Zhang, and Y. H. Liu. 2013. “Design of Deformation Monitoring Terminal System Based on STM32,” Applied Mechanics and Materials, Vols. 347-350, pp. 628-633.
7. Z. Shi, P. Zhang, and A. Shu. 2010. “Forecast and early Warning System for Debris Flow Monitoring,” Journal of Yangtze River Scientific Research Institute, 27(11): 116-119.
8. Y. Su, J. Cao, and L. Cheng. 2016. “Application of ADS1256 in High Precision Data Acquisition System,” Electronic Science & Technology, 3(5):546-548.
9. M. Zhang, Z. Xiao, and Y. Yang. 2013. “Seismic Data Acquisition Circuit Design. Modern Electronics Technique,” 36(24):134-135, 139.
10. Z. Chen. 2017. “The Application of Synchronization Time Server of Dual-Mode Satellite: GPS/BDS,” China Medical Equipment, 14(6):117-119.