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Research and Development Trend of Landslide Deformation Monitoring Methods

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Abstract: In recent years, with the rapid development of science and technology, the deformation monitoring methods of landslide disasters have also begun to have more choices. This paper analyzes the four technical means of Interferometric synthetic aperture rad(InSAR), Global Navigation Satellite System(GNSS), 3D laser scanner, and shape acceleration array(SAA) one by one points out the advantages and disadvantages of these four technical means in landslide deformation monitoring, and also summarizes the development trend of these four technical means.

1. Introduction

A landslide is a common and frequent geological disaster, which is characterized by strong suddenness, great harm, and great difficulty in treatment. If the deformation and evolution of the landslide cannot be found in time and effective emergency measures are taken, it will lead to serious casualties, property losses, and social impact. China's geomorphologic and geological environment is very complex, with frequent landslide disasters, and more than 70 cities are facing the threat of landslides, More than 460 regions are also affected by landslides, which is very dangerous for the safety of people's lives and property, especially in southwest China like Tibet. As a result of multi-year wind and rain erosion, numerous landslides, and vertical and horizontal ravines gradually created sufficient geological-geographical conditions, as a result of which landslides occurred frequently, seriously affecting people's daily production and life, more than 85% of mountainous areas are at risk of landslides. It threatens the safety of human life and property. With the development of society and the advancement of science and technology, the scientific and reasoned professional monitoring of landslide disasters has become an important tool for scientific prevention and control of landslide disasters, and effectively reducing human casualties and property losses.

2. In SAR

2.1. Research Status of InSAR

InSAR is a synthetic aperture radar interferometry technique that combines interferometry with synthetic aperture radar technology and applies it to remote sensing and mapping radar technology. As an active microwave remote sensing technology, synthetic aperture radar records the phase information and polarization scattering information of ground objects mainly by transmitting electromagnetic waves and receiving wave feedback, as shown in Figure 1.

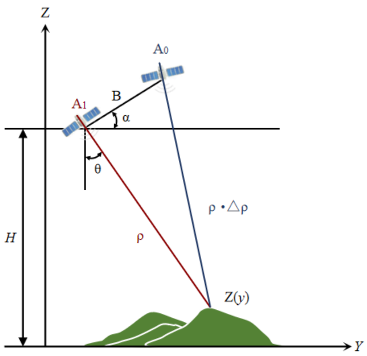

Figure 1: Principle of SAR receiving information

The phase information coneys the distance information between the target object and the sensor, while the polarization scattering information conveys the surface attributes, including water content, roughness, surface lithology, and surface object type[1], as shown in Figure 2. The main principle of InSAR is that the SAR image of the same area can be processed by complex conjugate multiplication to extract the deformation information of ground objects when it is passed twice or more.

SAR sensor	Run start and end time	revisiting period /days	Work band (wavelength /cm)	breadth /km	Resolution (azimuth to distance direction)	angle of incidence
SEASAT	1978.06—1978.10	17	L(23.5)	100	25m×25m	20°~26°
SIR-A	1981.11—1981.11		L(23.5)	50	40m×40m	47°
SIR-B	1984.10—1984.10		L(23.5)	50	40m×40m	15°~64°
ERS-1	1991.07—2000.03	35,3,168	C(5.63)	100	30m×30m	20°~26°
ERS-2	1995.04—2011.09	35,3	C(5.63)	100	30m×30m	20°~26°
				Fine:50	9m×(8.9)m	37°~47°
RADARSAT-1	1995.11—2013.03	24	C(5.63)	Standard:100	28m×(21~27)m	20°~49°
				canSAR:500	28m×(23,27,35)m	20°~45°
				AP mode:58-110	30m×(30~150)m	15°~45°
				Image:58-110	30m×(30~150)m	15°~45°
ENVISAT	2002.03—2012.04	35,30	C(5.63)	Wave:5	10m×10m	15°~45°
				GM:405	1km×1km	17°~42
				WS:405	150m×150m	17°~42°

Figure 2: Specific parameters of the SAR satellite system[1]

The ERS (European Remote Sensing) 1/2 series of data mainly provided monitoring data for landslide dynamics in the early stage. Based on the traditional D-InSAR technology, the early results of landslide deformation monitoring were obtained. With the development of science and technology, in the face of complex geological environmental problems such as topographic relief, vegetation, and landslides, people gradually find that InSAR observation of landslides is still difficult. To solve these problems, relevant researchers began to associate MT-InSAR with landslide gradual deformation monitoring.

Li et al.[2] concluded that InSAR technology provides important support for landslide control from "post-disaster analysis" to "pre-disaster prediction and recognition". At the same time, the multi-source/remote sensing fusion monitoring technology based on InSAR and complementary to other remote sensing technologies is becoming an important tool for qualitative and quantitative disaster application research in landslide research.

However, land subsidence monitoring is the main target of MT-InSAR technology, and it can not be effectively applied in landslide monitoring. In addition, geometric distortion caused by topographic relief and low coherence caused by vegetation cover is still the main problems faced by InSAR landslide monitoring,[3,4] and it is still difficult to obtain effective and accurate monitoring results. On the other hand, more than 400 Earth remote sensing satellites are currently in orbit, so the received remote sensing image data is also very large. If the landslide is judged by manual interpretation of data as before, such a large workload has been difficult to carry out.

2.2 Development Trend

With the continuous collection of satellite data, theoretical methods have also begun to improve. InSAR technology has matured in the dynamic monitoring of individual landslides. It can be seen that InSAR has changed from technical dominance to practical application in landslide research. However, at present, the important problem faced by InSAR is still data processing, and relevant researchers should gradually solve it. In the future, the in-depth integration of InSAR and landslide disaster monitoring should also continue to focus on exploration. In view of how to solve the problem of manual interpretation of remote sensing images, machine learning has also begun to be used in the development of remote sensing image-related technologies in recent years. Because deep learning can achieve high intensity imaging learning, analysis and prediction, it is also inevitable to use it to pursue the automation, intelligence and rapid identification of landslide disaster monitoring.

3. GNSS

3.1 Research Status of GNSS

GNSS (Global Navigation Satellite System) has been widely used in the field of landslide monitoring in recent years due to its high accuracy, no need for alignment between stations, full automation, continuous three-dimensional positioning and other advantages. With the advent of GNSS monitoring technology, the traditional landslide deformation monitoring gradually began to use positioning technology to carry out space observation and transformation, Its working principle is shown in Figure 3. At present, there are more than 120 GNSS satellites in orbit, which have continuously promoted the universal application and development of GNSS in recent years[5].

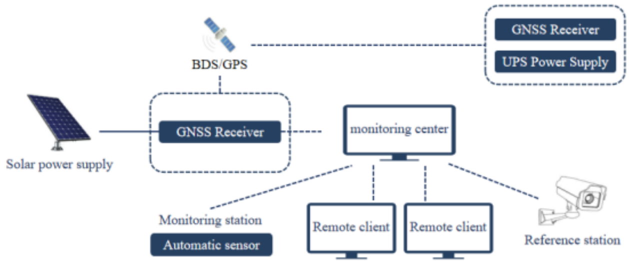

Figure 3: Working principle of GNSS

On the one hand, the original GPS monitoring technology is gradually limited in its own technology and the requirements of landslide monitoring specifications, on the other hand, it is also faced with the challenges of monitoring difficulty, high monitoring cost and complex monitoring caused by too dense wild bushes. The monitoring data calculation of complex geological environment has low monitoring accuracy and reliability. Therefore, the application of this technology in landslide deformation monitoring has certain limitations. In recent years, with the continuous development of GNSS technology, GNSS measurement technology has developed from static measurement, fast static measurement, post-processing high-precision measurement to dynamic real-time RTK measurement mode[6]. Now it can track and monitor the whole process of the landslide from stability to destruction in real time in a natural state. At the same time, with the advent of the non-differential high-precision GPS single-point absolute positioning technology, GPSPPP has realized that the GNSS monitoring technology can independently monitor landslide deformation without any installation. With the establishment of China's main geographic database and the establishment of the Beidou Navigation Satellite System (BDS), the GNSS landslide deformation monitoring technology has begun to receive attention and has been widely used in the field of landslide deformation monitoring in China. GPS technology can obtain more continuous, reliable, and accurate monitoring data in landslide-prone areas. Under such monitoring conditions, the losses caused by landslide disasters can be reduced more timely and effectively.

GNSS monitoring still faces many challenges, and the cost is also the main challenge faced by experts when conducting large-scale GNSS landslide monitoring. On the other hand, GNSS equipment has high energy consumption and operates the landslide monitoring system 24 hours a day, so it is difficult to use solar energy for uninterrupted power supply in case of overcast and rainy weather. In terms of equipment deployment, due to the need for manual on-site installation, it is difficult to deploy in high remote landslides and other geographical environments, which is an urgent problem to be solved. The landslide monitoring technology can achieve accurate landslide early warning. The main reason is that it has the ability of high-precision real-time monitoring, which meets the requirements of real-time monitoring accuracy less than landslide deformation. This is the basic principle of landslide deformation monitoring. However, there are still many errors in GNSS positioning sequence under complex landslide environments[7], which seriously affects the availability and reliability of GNSS landslide deformation monitoring8. In recent years, researchers have also been discussing this issue.

3.2 Development Trend

How to improve the accuracy of GNSS positioning by using LEO9 satellites and carrying out multi-source data fusion processing such as network MEMS10,11, RTK12,13, and GNSS under large altitude differences in large areas will be the research focus of improving the accuracy14,15 of GNSS landslide monitoring technology in the future. The essence of ensuring the success of GNSS landslide warnings is to improve the availability and reliability of GNSS in complex scenarios. The process of landslide monitoring must be a cross-technology and complete process. The premise of the overall data quality control is to cover the whole process, from data acquisition to calculation to accuracy improvement to ensure the availability and reliability of GNSS real-time deformation monitoring data. In terms of equipment deployment, it is necessary to continue the study of the unmanned deployment of contact slip monitoring equipment and technology[8-9].

4. 3D Laser Scanner

4.1 Research Status of 3d Laser Scanner

As a new type of fully automatic and high-precision 3D scanning technology, as shown in Figure 4, A 3D laser scanner can quickly obtain continuous, dense, and comprehensive image data and 3D coordinate data of the measured object surface. The 3D laser scanner is mainly composed of a support system, scanning system, and laser ranging system. In addition, it integrates digital photography and an instrument internal calibration system. Based on the TOF (Time of Flight) pulse ranging principle16, the principle of obtaining the data coordinates of the scanned target point cloud is as follows: the laser beam emitting device in the scanner emits millions of lasers every time, and these laser pulses affect the pulses on the target equipment, which are received and processed by the receiving equipment to obtain information. Since 2005, a small number of scholars in China have begun to study the application of 3D laser scanners in slope monitoring[10-11].

There are two main types of deformation monitoring technology: (1) "point" monitoring (GPS, extensometer, total station, laser, radar range finder); (2) "Surface" monitoring (photogrammetry, satellite, and ground radar interferometry, ground laser scanning measurement and airborne laser scanning measurement)[12-13]. Generally speaking, the "point" monitoring technology can obtain high-precision measurement data, but its limitation is that only a small number of known specific point data can be obtained, but not the whole shape of the landslide. The ground-based 3D laser scanner does not constitute a monitoring point for data acquisition, so the feedback of the sliding surface topography is faster and more accurate than the traditional monitoring method17, and the acquisition of surface deformation value is also faster. In the face of sudden changes in the rapid deformation stage and landslides in the disintegration stage, 3D laser scanners can perform real-time "face", high-precision, non-interference monitoring and all-weather work, and reliable and continuous data can play a key role in the prediction of landslide disasters. Therefore, the 3D laser scanner is more effective and convenient than traditional measurement technology to obtain landforms[14-15].

Figure 4: 3D laser scanner

When two scanning points of the 3D laser scanner appear repeatedly, the deformation amount cannot be directly obtained, which is a defect to be solved; On the other hand, the landslide monitoring area is mainly mountainous, with a wide range, complex terrain, and difficult data collection. In addition, there is dense vegetation on the landslide in the monitoring area, resulting in point cloud noise, which will also affect the quality of point cloud data and greatly limit the freedom of the monitoring station. The data structure mode and measurement method of ground 3D laser scanning technology is very different from traditional measurement methods, and its data processing method is also completely different from existing theoretical methods. There are still many theoretical and practical problems in landslide deformation monitoring, and relevant researchers need to further study[16-17].

4.2 Development Trend

The 3D laser scanner has both advantages and disadvantages in dynamic monitoring of landslide risk. The most important requirement for it to perform various dynamic monitoring tasks is high accuracy and efficiency. At present, strengthening the ability of laser scanning to process data, and how to improve the sensitivity of laser scanning, as well as the large change of laser volume under different volume ratios, have become the focus of relevant scientific researchers in recent years[18].

5. SAA

5.1 Research Status of SAA

SAA (shape acceleration array) is a new geotechnical engineering monitoring instrument based on micro-manufacturing technology and microelectronics technology, as shown in Figure 5. It has many advantages, such as low power consumption, small size, large data volume, large range, high accuracy, high frequency, high stability, etc. T. Abdoun et al,18 In addition, it can also realize real-time monitoring automation, which greatly saves labor costs and is very conducive to the establishment of a landslide early warning platform, so that the landslide disaster information can be released in a timely and effective manner to meet the requirements of landslide early warning and prediction.

Figure 5: Shape acceleration array

At present, there are still not many application examples in China. In addition, the cost of SAA instrument purchase is high, and the relevant domestic professionals lack experience in use and maintenance. SAA monitoring landslide deformation will take some time to become more mature.

5.2 Development Trend

At present, SAA has not been widely applied in China, but it can complete the task of automatic monitoring of deep displacement, especially for large deformation monitoring of landslide mass. With the continuous understanding and learning of researchers, SAA can be widely used in landslide disasters shortly.

6. Conclusion

InSAR, GNSS, 3D laser scanners, and SAA have their advantages and disadvantages. At present, geographic information technology, earth science, remote sensing technology, and computer technology have developed rapidly. In the aspect of disaster early warning and monitoring, various advanced technologies have been applied to transform from independent development to cross-integration. The deformation monitoring data also began to be tracked with multi-dimensional, high-precision, and high spatial-temporal resolution for the practical application of geological landslide disaster prediction and early warning. In the future, with the gradual maturity of multi-disciplinary integration technology, the continuous emergence of new monitoring tools, and the more reasonable collection and application of in-depth monitoring data, the landslide deformation monitoring technology will make great progress, which will help to provide long-term and effective technical support for landslide early warning and treatment, mechanism research, and stability evaluation.

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