

Application and Problems of Low-altitude Remote Sensing Technology in Geological Disaster Monitoring

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Abstract: The geological structure of our country is complex, with a wide area of mountains and hills, and once a geological disaster occurs, it can cause huge damage. Therefore, researching how to monitor geological disasters has significant practical significance. The paper summarizes the different techniques used by various scholars to monitor geological disasters using low-altitude remote sensing. Low-altitude remote sensing has emerged as a powerful tool for capturing high-resolution spatial and temporal data, offering real-time monitoring capabilities that traditional methods, such as satellite imaging, often cannot match. The current technical issues and prospects, the advantages and disadvantages of different technologies, and the direction for improvement are discussed. Combining multiple disciplines, such as geology, remote sensing, and geographic information systems (GIS), can better understand the underlying causes of these disasters and develop more accurate monitoring methods. It is significant to improve the response speed of disaster prediction by building a complete prediction chain. With the continuous development of monitoring systems, we can reduce the harm caused by geological disasters to the lives and property of the Chinese people.

Keywords: Landslide; Debris Flow; Low-Altitude Remote Sensing.

1. Introduction

The geological environment encompasses a wide range of content, such as hydrology and climate. These components interact with each other, but due to the development of social and economic activities, human activities have become more extensive, and the geological environment has also been greatly affected. As a result, the geological environment was damaged, leading to geological disasters. Geological disasters are geological actions that cause damage to human life and property, as well as environmental destruction, as a result of natural or human factors such as tectonic movements and engineering operations. The distribution and change patterns of geological disasters are both determined by the natural environment and closely related to human activities. They have the characteristics of suddenness, uncertainty, concealment, etc. Geological disasters pose a serious threat to people's lives and property safety. Once they occur, the harm caused cannot be estimated.

According to the survey, mountainous and hilly areas account for about 65% of China's total land area. The geological environment conditions are extremely complex, with frequent geological activities and a high frequency of geological disasters. According to data provided by the China Geological Survey, China has been the country with the most serious geological disasters and the largest population threatened in the world in recent years. Geological disasters, including landslides, mudslides, and earthquakes, seriously impact China's economic development, population, and ecological environment. The 19th CPC National Congress proposed building a science and technology powerhouse, and remote sensing monitoring has become a hot topic of concern among various sectors of society. With the rapid development of remote sensing technology, effectively utilising remote sensing monitoring has become an important development direction. Low-altitude remote sensing monitoring technology has the characteristics of safety, convenience, low cost, high clarity, and wide application range [1]. Many scholars have conducted in-depth research on remote sensing systems. Sun et al. [2] studied the differences between drone low-altitude remote sensing

monitoring and satellite remote sensing from this perspective. Then, the importance of low-altitude remote sensing monitoring in the field of geological disasters was emphasized again.

This paper researches the monitoring and prevention of specific geological disasters (landslides and mudslides) using low-altitude remote sensing monitoring technology, and the results are derived through a review method. Low-altitude remote sensing has a milestone significance in dynamic monitoring of geological disasters, reducing the losses caused by disasters. It safeguards the lives of people and promotes the construction and development of low-altitude remote sensing.

2. Low-Altitude Remote Sensing Survey and Monitoring Data

Low-altitude remote sensing surveys and monitoring data are among the most important and reliable data in the field of geological disasters. Low-altitude remote sensing refers to the remote sensing technology to obtain land surface information from a lower flight altitude (usually several hundred meters to several thousand meters). It can collect high-resolution geographic and environmental data, such as images, video, and point cloud data, through sensors mounted on the aircraft. The survey data includes the geological, hydrological, and meteorological conditions of ground hazards in geological disaster areas. The monitoring data is relatively abundant, and the monitoring of landslides mainly includes displacement monitoring (such as GPS/GNSS and total station instruments), monitoring of geological bodies (such as soil moisture and pore water pressure) and triggering conditions (such as precipitation and earthquakes).

Unmanned aerial vehicle (UAV) Remote Sensing (UAVRS) is an advanced aerial remote sensing technology solution that utilizes advanced UAV technology, remote sensing sensor technology, telemetry and telecommand technology, communication technology, POS (Position and Orientation System) positioning and orientation technology, GPS differential positioning technology, and remote sensing application technology. Compared with traditional remote sensing platforms, UAVs are flexible, low-cost, and easy to operate. It can fly at low altitudes and obtain higher-resolution data, which is especially suitable for high-precision monitoring and investigation in small areas. It can automatically, intelligently, and professionally acquire spatial sensory information on land, resources, environment, and events and process, model, and analyze it in real time. The UAV Remote Sensing System is an unmanned aerial remote sensing system that uses UAVs as a platform, various imaging and non-imaging sensors as the main payload, and flies at an altitude of several kilometers, capable of acquiring remote sensing imagery, videos, point clouds, and other types of data.

Currently, the mature and complete civilian UAVRSS mainly consists of flight platform systems, lightweight multi-functional ground observation and sensing systems, remote sensing airborne interactive control systems, ground data rapid processing systems, data transmission links, comprehensive support systems, and devices, and ground logistic personnel [3]. In actual applications, UAVs are often equipped with multiple sensors, such as SAR (Synthetic Aperture Radar) and its extended technology equipment, onboard LiDAR (Light Detection and Ranging), oblique aerial photography, and orthophoto aerial photography equipment. These sensors can be flexibly mounted according to mission requirements and used to acquire low-altitude remote sensing data. For example, in geological disaster monitoring, UAV remote sensing can monitor the surface changes and dynamics of landslides, debris flows, and other disasters.

3. Case Study

3.1. Issues and Monitoring of Landslide Disasters

3.1.1. Study of Landslide Disaster

Landslides are prone to occur, which refers to the likelihood of geological disasters under specific conditions. They are natural phenomena in which rock, soil, or debris slide down a slope due to gravity. Landslide hazards can occur when the stability of slopes is affected by, for example, heavy

rainfall, earthquakes, volcanic activity, erosion, or human activities (such as deforestation and construction).

The core idea of landslide evaluation is to use bivariate or multivariate statistical analysis on the geological and environmental conditions of the areas where geological disasters have already occurred to evaluate the areas where geological disasters may occur.

Scholars often use a single machine learning algorithm, such as SVM, RF, and ANN. After comparing the accuracy of different models, scholars generally believe that the RF model has a high prediction accuracy and stronger model adaptability, and it is a reliable landslide susceptibility prediction model. In addition, the XGBoost model proposed by Chen is one of the most popular machine algorithms. Compared to traditional machine algorithms, it has faster computation speed and stronger generalization ability [4, 5]. Zhang applied it to landslide susceptibility assessment. They analyzed the superiority of the model in terms of generalization ability by taking the Shanxi Liliu coalfield as an example [6].

Additionally, some scholars have utilized other algorithms to assess landslide methods quickly. Shirzadi [7] compares various algorithms and estimates the sliding force by calculating the area of the sliding plane, concluding that the ANFIS has better calculation results.

3.1.2. Monitoring Landslide Problems

Current and Dynamic Issues: Monitoring landslide disasters requires quick and accurate results. Traditional machine model algorithms have certain limitations in handling large amounts of data. They are difficult to update quickly and have poor adaptability in dynamic environments.

Parameter issues: Classic algorithms often contain multiple parameters that need to be adjusted, and changes to these parameters will directly affect the model's performance. In the landslide disaster field, due to a lack of sufficient experimental experience, parameter optimization often faces certain problems.

Currently, there is a severe shortage of available data in the field of geological disasters, and high-precision remote sensing data is very expensive. Additionally, a large amount of field monitoring and experimental data has not been made public, resulting in a severe shortage of available data.

3.2. Issues and Monitoring of Debris Flow Disasters

Debris flow, among the more common, frequent, and widespread geological disasters, not only endanger human safety but also cause considerable damage to property. Because the probability of accurate prediction of geological disasters is not high at present, protecting human life safety and minimizing property losses has become the top priority in the process of dealing with landslide and mudslide disasters. The key to solving this problem lies in using various means to interpret the disaster and estimate secondary disasters as soon as possible after the disaster, and rescuing and evacuating people in time. Currently, the main way to obtain post-disaster information is through low-altitude remote sensing to obtain high-resolution image products. Remote sensing techniques commonly used in landslide monitoring include optical remote sensing, SAR, LiDAR, thermal imaging, multispectral and hyperspectral remote sensing, UAV and satellite remote sensing, etc. These technologies help identify and monitor early signs and trends of landslides by obtaining high-resolution images, accurately measuring surface deformation and analyzing key parameters such as surface temperature, humidity and vegetation. In particular, SAR and InSAR technologies can monitor millimeter-level surface displacement, LiDAR generates accurate three-dimensional terrain models, and drone remote sensing can cover landslide areas flexibly and efficiently. Due to its limitations, this method has played an important role in disaster relief and rescue, but the ordinary low-altitude remote sensing technology still needs ground control points to participate in absolute orientation [8].

This paper takes DGPS-assisted low-altitude remote sensing as its specific research object. Real-time DGPS-assisted low-altitude remote sensing combines real-time DGPS, a widely used RTK technology, and low-altitude remote sensing technology, which utilizes RTK technology to obtain

high-precision position coordinates and thus eliminates the need for ground control points. This combination greatly enhances the efficiency and accuracy of spatial data collection, particularly in dynamic environments such as geological disaster monitoring.

Carrier phase differential is a method widely used in RTK technology that can achieve sub-centimeter accuracy in real-time differential and has the observation quantities of the phase difference between the user and the reference station receiving signals. By using the single-difference method, double-difference method, and triple-difference method, various systematic errors, such as satellite clock errors, atmospheric delays, and multipath effects, can be effectively mitigated. This multi-difference approach ensures that high-accuracy positioning can be maintained in real-time, even in challenging environments, essential for low-altitude remote sensing applications.

Current Problems of DGPS are as follows: (1) Further enhance the quality and stability of real-time DGPS hardware, including the receiving frequency and signal anti-interference ability, to improve the system's ability to continuously operate at high speeds and long distances. (2) Develop multiple real-time DGPS assistance modes, utilizing other transmission channels, to maximize signal strength uniformity and stability.

3.3. Issues and Monitoring of Collapses

Collapses, which often occur with high uncertainty and strong destructiveness, are difficult to predict and monitor due to their evolutionary patterns. The formation conditions of landslides mainly include geomorphological conditions, structural and construction conditions of slope rock and soil, as well as the influence of water and other factors. These conditions work together to cause the rock and soil body to suddenly detach from its parent mass, collapse, roll, and accumulate at the foot of the slope or in a valley.

There are many technical difficulties in the continuous monitoring of geological disaster bodies at present. Relying on human labor to record and investigate on-site incurs high costs in manpower and material resources, and it is difficult to conduct investigations and there are many blind spots, which often fails to achieve the expected investigation and measurement effects. Moreover, satellite monitoring has problems with poor timeliness and low accuracy, and it cannot identify the faint cracks of collapsing bodies or research the trend of crack changes. Therefore, conducting research on the application of UAV remote sensing technology in landslide geological disasters provides a new technical method for dynamic monitoring of such disasters. Using this technology to collect optical imaging data of the disaster body at different times can achieve continuous monitoring of the disaster body [9].

In low-altitude drone remote sensing images, information related to landslides is usually more obvious, and the characteristics of landslide bodies are much more recognizable than those identified in satellite remote sensing images. Several factors contribute to this improved clarity: (1) The vegetation coverage at the location of the landslide is significantly lower than that of the surrounding area, especially there is almost no vegetation growth on the newly formed landslide. (2) The slope where the landslide occurs is usually quite steep, and most of the elevation changes are large. (3) Before the collapse front and in the middle of the collapse body, there is often a phenomenon of accumulation of loose stones. (4) There are numerous cracks in the collapsing mass and instances of rocks separating from the rock mass.

For data collection in this study, the Rie-DB8 (RP103) octocopter drone produced by Chengdu Ruibo Technology Co., Ltd. and the Riy-S5 five-lens oblique digital aerial photography instrument were employed. Using the 3D modeling software Context Capture to create a 3D model, a high-definition 3D photorealistic model is obtained by preprocessing data, triangulation, texture selection, and texture matching. From the model, it can be seen that there are obvious cracks in the rock mass of the disaster body due to the development of joints, coupled with post-weathering. The vegetation around the geological disaster is well developed, and due to the long duration of the disaster, sparse vegetation

has appeared on the debris accumulation of the collapse, and the damage to vegetation caused by the collapse is basically no longer visible [10].

4. Discussion

Ground investigation and monitoring data mainly include geological hazard area's basic geological data, as well as data on displacement monitoring, geological body monitoring, and monitoring of triggering conditions at the site. These traditional ground survey methods are often labor-intensive, costly, and may have data blind spots due to terrain limitations.

Classic machine learning algorithms have become indispensable tools in landslide identification and vulnerability assessment, providing advanced methods to analyze complex interactions between geological factors and the environment. Through comparative analysis, RF has high accuracy and low uncertainty in geological disaster susceptibility evaluation and is a reliable and accurate susceptibility prediction model. XGBoost model has faster computation speed and stronger generalization ability than traditional machine learning algorithms.

The combination of UAV-assisted low-altitude remote sensing technology and machine learning algorithm provides a promising direction for the development of landslide monitoring and vulnerability assessment in the future. Uav remote sensing technology can provide detailed high-resolution views of landslide areas and accurately identify key features such as cracks, slope steepness, and vegetation loss. The technology can capture data simultaneously, continuously monitoring dynamic changes in landslide-prone areas.

5. Conclusion

By studying the nature and causes of landslides, it has been found that landslides are prone to occur. Meanwhile, with our complex and diverse terrain and the impact of human engineering on slope stability, the likelihood of landslides occurring has increased significantly. Utilizing geology, remote sensing science, geographic information science, and other methods and applying current analytical models to identify problems and determine future directions. Develop dynamic prediction models. Currently, there is a lack of real-time data on geological disasters, and no complete system exists. Therefore, the various prediction aspects of geological disasters can be integrated to form a complete prediction chain, which is of great significance in improving the response speed of disaster prediction. Under the constant monitoring of the system, the harm caused by geological disasters to the lives and property safety of the Chinese people can be reduced.

Based on the low-altitude remote sensing 3D oblique photography technology of UAV, dynamic monitoring of the collapse geological disaster at the checkpoint was achieved, and good results were obtained. The following conclusions were drawn: (1) Using low-altitude aerial remote sensing technology with drones can enable the investigation of geological disaster bodies and achieve digital preservation of geological disasters, providing powerful data support for later research on the development state of geological disaster bodies. (2) Using UAV low-altitude remote sensing technology to monitor and analyze the evolution of landslides in real time can effectively assess the trend of geological disasters and the risk of geological disasters, providing effective and targeted suggestions for the prevention and treatment of geological disasters.

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