Research on Methods and Application of Remote Sensing Technology in Geological Hazard Monitoring and Management

Tengfei Qu¹, Gen Tian², Mingxiu Tang³

¹Shandong University of science and technology, Tai’an, Shandong, 271019 China
²School of Electronic Engineering, Tianjin University of Technology and Education, Tianjin, 300222 China
³College of Geomatics, Shandong University of Science and Technology, Qingdao, Shandong, 266590 China

Abstract. In recent years, remote sensing technology has developed rapidly, and it has been increasingly used in the investigation and monitoring of geological hazards. Based on this, this article studies the research methods and applications of remote sensing technology in the monitoring and management of geological hazards. First introduced the concept of remote sensing technology and its advantages in information acquisition in disaster areas, and then briefly described the development process and current status of remote sensing technology. Then analyzed the research methods of remote sensing technology in geological disaster investigation, including the establishment of interpreted signs and interpretation of typical disasters in the survey area. Finally, the detailed application of remote sensing technology in earthquake and landslide disasters is explained in detail, and the future development direction of remote sensing technology in geological disasters is pointed out. Only continuous innovation and research can remote sensing technology be better used in disaster prevention and monitoring.

1. Introduction

As one of the most damaging natural disasters in the world, geological disasters are endangering the safety of human life and property. With the continuous progress of society, the degree of detection of geological disasters in China has been strengthened in recent years. With the development of remote sensing technology, the concrete practice has played a huge role in monitoring and preventing geological disasters. This technology can not only provide effective early warning of geological disasters, but also achieve effective prevention and control of geological disasters, reduce the degree of damage to geological disasters, and guarantee life and property safety of local people [1].

2. Concepts and Advantages of Remote Sensing Technology

Remote sensing is a science and technology based on the interaction between electromagnetic waves and material on the surface of the earth, detecting, analyzing and studying the resources and environment of the earth, revealing the spatial distribution characteristics of the elements on the
surface of the earth and the law of temporal and spatial changes [2]. It is fast, safe, and free from the obstacles of terrain and landforms. The remote sensing images are intuitive, accurate, and rich in information. They can play an important role in geological disaster emergency mitigation and assessment.

Compared with conventional information collection methods, remote sensing technology has obvious advantages in acquiring information in disaster areas, mainly in the following aspects:

1) Wide coverage. Remote sensing technology can observe and collect data in a large area of the affected area, and reflect the situation of the affected area from a macro perspective. For example, a scene TM image can cover the surface area of 185km×185 km, which is equivalent to being able to cover the entire area of Beichuan, which was the worst affected by the Wenchuan earthquake. Large-scale data acquisition capabilities provide powerful conditions for the study of global climate change and regional geological activities.

2) Fast acquisition speed and many methods. Remote sensing technology can periodically observe the disaster area to acquire images at different time periods. Through the comparative analysis of remote sensing images before and after the disaster, not only can the disaster area be estimated, the impact range can be estimated, but also dynamic changes in the disaster situation can be tracked.

3) Large amount of information. Remote sensing can detect the electromagnetic radiation energy in different wavelength ranges such as visible light-reflected infrared, thermal infrared and microwave to obtain vegetation coverage, soil moisture, regional geology, hydrogeology, environmental pollution, forest fires and the surface information such as morphology [3]. The resolution of different remote sensing images is between tens of centimeters and hundreds of kilometers, which can meet the application needs of disaster reduction and relief at different scales.

In the past 20 years, with the in-depth research of aerospace ground observation technology, computer technology and electromagnetic wave information transmission technology, remote sensing technology has developed rapidly, an important step in the practical direction has been taken, and it is widely used in various land and resources surveys and environmental assessments and disaster monitoring.

3. Development of Remote Sensing Technology

The application of remote sensing technology to geological hazard investigation can be traced back to the end of the 1970s. In foreign countries, Japan, the United States, and the European Union have carried out well. Japan used remote sensing images to compile geological hazard distribution maps across the country. Based on a large number of landslide and debris flow remote sensing surveys, the countries of the European Union have systematically summarized the remote sensing technology and methods, and pointed out the spatial resolution of remote sensing images needed to identify landslides and debris flows of different scales, different brightness or contrast, and remote sensing technology. Combined with the classification method of ground survey, GPS measurements and radar data can be used to monitor the possible extent of landslide activity.

China's use of remote sensing technology to carry out geological disaster surveys started late, but progress has been rapid. China's remote sensing surveys of geological disasters have gradually developed during the construction of large-scale projects in mountainous areas or the prevention and control of floods in large rivers. In the early 1980s, Hunan Province took the lead using remote sensing technology, the geological environment and geological hazard investigation of water conservancy projects have been carried out in the Dongting Lake area. Since the mid-1980s, large-scale surveys have been carried out along Baocang, Baotian, and Chengkun railways. Aerial photography provides a source of information for investigating the distribution of geological hazards. Since the 1990s, remote sensing survey techniques for geological hazards have also been used in trunk road and railway route selection, such as along the Beijing-Kowloon Railway. In the "Provincial Comprehensive Survey of Remote Sensing of Land and Resources" carried out within the province, each province (autonomous region) has set up a special small and medium scale "geological disaster remote sensing comprehensive survey. "The subject of "survey" is mainly to identify the
geomorphological micro-landscape types and activities, and to evaluate the impact of geological disasters on the construction and operation of large-scale projects. Especially in recent years, major geological engineering demonstrations have carried out engineering geological remote sensing surveys, such as Hangzhou Bay Cross-sea bridge, Xiangshan port cross-sea bridge, etc.

In the past 20 years of practice, we have explored a more reasonable and effective method for remote sensing surveys of geological disasters such as landslides and mudslides, that is, using remote sensing information sources, mainly visual interpretation, supplemented by computer image processing, and interpreting remote sensing in key areas. The results are combined with field verification, and other non-remote sensing data are used for comprehensive analysis and multi-party verification.

In summary, the remote sensing survey of geological hazards has basically completed the demonstration experimental stage and is moving towards the practical stage of comprehensive promotion. It has particularly broad application prospects in large-scale project construction in mountainous areas and disaster prevention and mitigation work in rivers, lakes, and reservoirs. Many geological hazard investigations have been applied in technology, and many successful experiences have been made. However, in the field of geological hazard monitoring, there are not many successful examples. Making full use of aerospace remote sensing, differential interference radar, and global positioning system technology and their integrated technologies for geological hazard monitoring is the inevitable development trend of the future remote sensing ground observation technology system in the application of geological hazard monitoring.

4. Research Methods of Remote Sensing Technology in Geological Disaster Investigation

4.1. Signs of Interpretation

Different ground features have different characteristics in remote sensing images, and the interpretation marks refer to these influential features that can be used to identify the ground features [4]. When establishing remote sensing interpretation marks, we must consider from multiple aspects, for example, size, position, color, shadow, shape, texture, etc. At the same time, when interpreting the interpretation, you must also consider whether there are other factors, so as to ensure the detail and accuracy of the interpretation and avoid missing judgments. The establishment of an interpretation mark requires a comprehensive analysis of its influence characteristics.

4.2. Interpretation of Typical Geological Disasters In The Survey Area

The geological disaster individual and the surrounding environment are different in the remote sensing image map, and the morphology and hue are different. We can interpret the disaster point through the abnormal response of the geological disaster individual presented on the remote sensing image map, and then check one by one to remove the fake ones, and determine the detailed disaster points in combination with the field review work.

4.2.1. Collapse. In the remote sensing image, we mainly refer to the anomaly of the collapsed surface formed by the collapse to interpret the collapse interpretation mark [5]. Through the interpretation of the survey area, we find that the collapse generally occurs in steep slopes, such as highways, near the river etc., the colors in the remote sensing image are mostly grayish white and light gray, without shadows, the shape is mostly crescent or block, and the texture is rough. Because the collapse area is generally small, there are certain difficulties in remote sensing interpretation. Generally, only newly developed collapses can be found according to remote sensing images, and field surveys are mostly used to find and determine the collapse.

4.2.2. Landslide. Landslides are the most common geological phenomenon in the loess region. When interpreting geological disasters in remote sensing images, you can interpret the location, size, physical image characteristics such as scale [6]. In this study, by interpreting the loess landslides in the
survey area, it was found that there are certain rules for landslides, which are generally distributed on slopes of 30° ~ 60° and mostly circular arcs. The boundary of the image is generally easier to determine, because the gullies are often developed on both sides of it. The anomalies shown on the image of the landslide wall are generally abnormalities in texture and tone, including tone anomaly lines and terrain, and steep ridge lines. Light green or green, the texture is patchy and rough, no shadow, and the shape is mostly arc or oblative. And we can analyze the software according to the scale and direction of the remote sensing image to get the length, width and sliding direction of the landslide.

4.2.3. Cracks. For the interpretation of cracks in remote sensing images, we can get the position, size, and stability of the cracks. The cracks are small, and the interpretation on the remote sensing image is based on the observation form, texture, hue, and shadow. The color of the crack on the remote sensing map is black or light gray, with shadows, the shape is strip or band, the length is different, generally there are more on both sides of the beam top, the texture is band and rough, the focus of interpretation is in terms of shadows and textures, there are major difficulties in visual interpretation. Generally, it must be combined with topographic maps, and interpretation methods combining visual and human-computer interaction are used.

4.2.4. Cut slope. On the remote sensing topographic map, slope cutting activities can be divided into two types: road cutting and kiln cave cutting slope. The hue and texture are the most important interpretation signs on the remote sensing topographic map. The remote sensing image map shows light gray and no shadow. The shape is mostly ring-shaped or crescent-shaped, mostly near the top of the beam or near the foot of the slope, with a small size and rough texture. The kiln cutting will seriously damage the stability of the slope and easily cause geological disasters such as landslides and collapses. It has brought great harm to people's lives and property safety. As residents in the survey area often build kiln on those landslide walls, during the field review process, we found that these abandoned landslide walls built on the old landslide wall cave dwellings can easily cause the landslide wall to slide again.

5. Application of Remote Sensing in Geological Disasters

5.1. Application of Remote Sensing Technology In Earthquake

China is located between the Pacific Rim earthquake zone and the Eurasian earthquake zone, and is one of the countries with the most severe earthquake disasters in the world. After a large earthquake, especially in the western mountainous regions of China, it often leads to large-scale sub-geological disasters. The input of a strong earthquake energy will induce a large number of geological disasters such as collapse, landslides, mudslides, etc., which will not only cause a large number of casualties and property losses, but also seriously hinder the smooth implementation of emergency rescue and post-disaster recovery and reconstruction. Obtaining disaster information, especially the distribution information of secondary geological disasters, is of great significance to resist scientific decision-making in earthquake relief and post-disaster recovery and reconstruction.

With the development of satellite and aerial remote sensing technology, after a devastating earthquake, remote sensing can be used to quickly obtain important post-earthquake disaster information such as building damage, road traffic damage, secondary earthquake and geological disasters, and ground surface rupture in the disaster area. Provide important decision-making information for earthquake emergency rescue, earthquake damage assessment, and reconstruction [7].

The application of remote sensing in earthquakes mainly includes the interpretation of images in earthquake-stricken areas, the analysis of the spatial characteristics of the disaster-stricken areas, and the evaluation of the intensity and intensity of earthquakes. It provides scientific and effective solutions for earthquake relief and minimizes casualties.
5.1.1. **Survey for earthquake and geological disasters.** High-resolution multispectral remote sensing technology has the advantages of wide observation range, fast speed, and safety, and it is not affected by terrain and landforms. Remote sensing images are intuitive, accurate, and rich in information. They can play an important role in earthquake disaster emergency mitigation and assessment, especially. In recent years, with the deployment and implementation of China's high-resolution Earth Observation System major project (referred to as high-score major project), high-resolution aviation and aerospace multispectral remote sensing technology has been vigorously promoted, which has promoted high-resolution multi-spectral remote sensing technology. The leap-forward development of spectral remote sensing data in the application of emergency monitoring and assessment of major natural disasters and emergencies.

The spatial distribution of these secondary geological hazards, especially the relationship with regional geological structures, intensity, and topography and geomorphology, combined with GIS technology can damage earthquakes comprehensive analysis and evaluation of forces. In order to give full play to the role of remote sensing technology in earthquake disaster emergency decision-making, rescue, and post-earthquake recovery and reconstruction, multi-source remote sensing data before and after the earthquake are used to interpret human-machine interaction based on remote sensing images and field investigations. In addition, through interpretation of remote sensing images, the disaster can be divided into residential areas and non-residential areas. The government should increase rescue efforts in residential areas to reduce the impact of earthquakes. On the other hand, through the interpretation of remote sensing images, post-earthquake remote sensing images can be used in combination with pre-earthquake aerial images, the automatic identification of co-seismic geological hazard maps, combined with visual inspection of images and field verification of disasters, can accurately record slope geological hazards [8]. Some insights can be drawn from the spatial analysis of disaster development laws.

At present, there are many types of sensors, different image resolutions, different time phases, and different spectral information. The single remote sensing data has certain limitations, which is not conducive to image interpretation and decision analysis. Multi-source remote sensing data using image fusion technology not only retains multispectral information and spatial information have also been strengthened, which is more suitable for human vision and computer classification. It can better take advantage of remote sensing technology in geological disaster investigation. At present, image fusion is mainly performed at three levels: pixel level, feature-level and decision-level. Pixel-level fusion is mainly performed on the original image. The biggest advantage is to maintain as much original information as possible and provide subtle information that cannot be provided by other fusion levels, which are roughly divided into two categories: spatial domain-based image fusion with image based on transform domain. Research proves that using full-color spot and multispectral TM images as data sources, data fusion algorithms and image quality evaluation can achieve good results.

5.1.2. **For the evaluation of seismic intensity.** The timely and accurate grasp of earthquake disaster information is an important guarantee for effective earthquake emergency rescue and minimizing earthquake disasters. The seismic intensity map is a scientific reflection of the distribution of the degree of damage caused by earthquakes, and it is also one of the main foundations of China's current earthquake relief [9]. The conventional method for seismic intensity assessment is to use a large number of professionals to conduct surveys and assessments at the site. The assessment of smaller destructive earthquakes generally takes 1-3 days, and the assessment of larger destructive earthquakes requires longer, or even takes dozens of days. How to improve the timeliness and efficiency of seismic intensity assessment has great application value. With the rapid acquisition of high-resolution remote sensing images of the disaster area, you can quickly estimate the distribution of earthquake intensity, estimate the disaster situation in the earthquake disaster area, and resist earthquake relief.
5.2. Application of Remote Sensing Technology In Landslides

Landslides are one of the most serious natural disasters in the world. Landslides have a direct or indirect impact on many countries, and there are increasing casualties, economic losses, and damage to the natural environment [10]. China’s earthquake landslides are widely distributed, especially in the mountainous areas of the west and southwest, many earthquake landslides will occur every time a large earthquake occurs, and a large number of hidden earthquake lagging landslides will be generated within a certain distance from the epicenter. If a large earthquake occurs in the lagging landslide area or its adjacent area, a landslide will occur. It will be more extensive and the disaster will be more serious.

Over the past few decades, the development of landslide identification, cataloging, sensitivity, and dangerous zoning technologies using remote sensing has made it an effective and economical technical means to improve land use planning, prevent disasters, and reduce casualties. Especially the development of remote sensing technology provides important information for analyzing, evaluating and determining the formation conditions and characteristics of landslides. At the beginning of the 21st century in China, Wang Zhihua proposed to use remote sensing imagery as a data source and comprehensively use GIS and other methods to analyze landslides and other geological conditions. "Digital landslide" technology for identification and analysis of disasters. Since the start of the large-scale survey of land and resources, the application of remote sensing survey technology for geological disasters, China National Geo-resources Aviation Geophysical and Remote Sensing Center has successively completed the investigation of the distribution and development environment of landslides and other geological hazards.

In general, remote sensing technologies such as aerial image interpretation, stereo image analysis, interferometry research, and laser detection and ranging systems (LiDAR) can be used for landslide identification, monitoring, and classification. Conventional methods in assessing slope instability can be used to quickly and easily obtain and update large area data, reducing field work and costs.

In recent years, various remote sensing technologies and analysis methods used in slope stability surveys abroad have made some new advances, such as the use of synthetic aperture radar (SAR) data to monitor surface deformation, and portable unmanned people with high spatial resolution. Mapping landslides, researching landslides using multitemporal remote sensing data, object-oriented image processing methods applied to landslide identification and classification, etc. By analyzing these feasible new methods, we can summarize the advantages of these methods and their issues worth noting during use and future directions.

6. Development Prospects of Remote Sensing Technology In Disaster Management

The development of aerial remote sensing technology will provide strong technical support for the investigation and monitoring of geological hazards. Using the various functions of geographic information systems and combining remote sensing technology, the survey and prediction assessment of geological hazards will be conducted in the survey area, and various comprehensive survey areas will be obtained. After the information, establish a geological disaster spatial information management system, manage geological hazard survey data, display and query the spatial distribution characteristics of geological hazards, evaluate the relationship between the degree of geological hazards, geological hazards, and factors, and propose reduction and prevention of geological hazards measures to predict possible geological disasters in the future.

At the same time, by selecting appropriate evaluation and prediction indicators, the geological hazard danger level is divided into the survey area, so as to provide a basis for geological hazard management, prevention, and early warning decision-making. In the future, the application of remote sensing technology in disaster reduction and relief in China will be applied to the following aspects:

(1) Formulate uniform application specifications.

Obtaining remotely sensed images is fast and extensive, and it can reflect the current situation in the disaster area in a timely manner, but for non-remote sensing professionals, it is quite difficult to grasp the information reflected by remotely sensed images. Therefore, it is necessary to organize
experts in remote sensing to develop science unified application standards and specifications of remote sensing technology to ensure the accurate expression of disaster information is an important way to improve the practical value of remote sensing information in disaster reduction and relief work. Establishing and improving a national-level remote sensing disaster monitoring, early warning, and evaluation system will be China's response reliable guarantee for large-scale sudden disasters.

(2) Strengthen the ability to acquire remote sensing data.
China's remote sensing technology has developed relatively late, and compared with developed countries, China's remote sensing technology is still not mature. Strengthen the construction of emergency response information networks, promote international and domestic remote sensing information sharing cooperation; build your own disaster satellite constellation system, establishing a stable and reliable source of remote sensing data to improve its own data acquisition capabilities is a data guarantee for remote sensing to play its technical advantage in disaster reduction and relief work.

(3) Improve the timeliness of remote sensing data processing.
Remote sensing data has a large amount of data and rich information, but it has affected the speed of data processing to a certain extent. However, when a large disaster occurs, time is life. Therefore, research on fast, efficient and automated data processing methods and technologies is to ensure the quality of information. At the same time, greatly improving the efficiency of data processing is also an important development trend.

7. Conclusion
The characteristics of remote sensing technology and the rapid development of other related high and new technologies have made possible the application of remote sensing technology in geological disasters. The increasingly serious geological disasters and the timeliness requirements for emergency geological disaster relief work, the application of remote sensing technology is extremely important to carry out the monitoring and management of geological disasters. What is necessary is the inevitable trend of the development of contemporary high-tech. Remote sensing technology can run through the entire process of geological disaster investigation, monitoring, early warning, and evaluation. The application of remote sensing technology in the monitoring and management of geological hazards has broad prospects.

References
[1] Gao Chunwei. Application of remote sensing technology in geological hazard monitoring [J]. Resource Conservation and Environmental Protection, 2018, (10): 47.
[2] Zhou Daquan. Application of remote sensing technology in geological disaster monitoring [J]. World Nonferrous Metals, 2018, (14): 27-28.
[3] Yun Pei, Hu Yifan, Wang Chen. Application of UAV low-altitude aerial photography remote sensing in emergency mapping support [J]. Science and Technology Information, 2016, 24: 2-3.
[4] Ye Weilin, Su Xing, Wei Wanhong, et al. Application of UAV aerial survey system in landslide emergency [J]. Bulletin of Surveying and Mapping, 2017 (9): 70-74.
[5] Gu Guangjie, Jiang Jian, Tao Zhanjie. Application of UAV tilt photogrammetry technology in emergency surveying and mapping support [J]. Surveying and Mapping Bulletin, 2017, Supplement: 100-101.
[6] Guo Dong, Wang Ke. Application and innovation of remote sensing measurement in geological disaster management [J]. World Nonferrous Metals, 2018 (06): 175 + 177.
[7] Lv Xiaofang. Application of remote sensing technology in geological hazard monitoring [J]. Building Materials and Decoration, 2018 (02): 223-224.
[8] Li Kun. Application of UAV remote sensing technology in geological hazard monitoring [J]. China Hi-tech Zone. 2018 (05): 132-135.
[9] Guo Min. Application of light and small drones in high geological disaster investigation [J]. Chemical Design Newsletter. 2018 (05): 118-120.
[10] Fu Haijun. Application of UAV remote sensing technology in geological hazard monitoring [J]. SME Management and Technology (1st Issue). 2017 (03): 108-110.