

Research on the application of multi-source remote sensing technology in landslide disaster

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Abstract. Remote sensing technology has become an important means of landslide disaster monitoring, especially Unmanned Aerial Vehicle (UAV), Interferometric Synthetic Aperture Radar (InSAR), and Light Detection and Ranging (LiDAR). In this study, a large number of relevant essays focusing on UAV, InSAR and LiDAR applied for landslide disaster monitoring were reviewed. Based on these research results, their respective strengths as well as the advantages of multiple combinations are analysed. The analysis results show that UAV is suitable for close and high-precision monitoring at small to medium scale, especially for post-disaster assessment; LiDAR focuses on high-precision terrain modeling and deformation monitoring, which is especially suitable for complex terrain areas; InSAR performs well for large-scale and long-term landslide monitoring. The combination of these three monitoring technologies tend to form a complementary monitoring and early warning system. The results are beneficial for improving the early identification and risk assessment ability of landslide disasters.

Keywords: UAV; InSAR; LiDAR; Landslide; Remote sensing.

I. INTRODUCTION

Geological disasters occur frequently in China with its complex geological environment and vast land area. Because of China being densely populated, the number of casualties caused by geological disasters is relatively large every year, and the economic losses are huge. In recent years, with the rapid development of science and technology, the application of remote sensing technology in landslide monitoring, identification and early warning has been paid extensive attention, and scholars all over the world have carried out a lot of research in this field and achieved remarkable results. In recent years, traditional ground surveys especially in the mountainous areas of western China are unable to satisfy the demand of high efficiency and precision for geological disaster prevention and control. Compared to traditional ground surveys, remote sensing technologies, especially unmanned aerial vehicles (UAV), Interferometric Synthetic Aperture Radar (InSAR), and Light Detection and Ranging (LiDAR), tend to acquire monitoring data for large areas more faster and more precisely. As a result, they provide strong technical support for the monitoring, early warning and rescue of geological disasters.

Unmanned aerial vehicle (UAV) remote sensing technology is widely used in the close-up monitoring and post-disaster assessment of landslide disasters. A monitoring system based on UAV remote sensing was established in Guizhou in China^[1]. UAV is used to collect a time series of high-resolution images over four years at seven epochs to assess landslide dynamics^[2],

and is used to describe the recent behavior of the landslide and to assess residual risk as well^[3].

InSAR is widely used for large-scale landslide monitoring and deformation detection, such as a case in Sichuan, China^[4]. Besides, InSAR is also introduced to make the long-term series analysis of the micro-deformation of the landslide body and finally monitor potential geological hazards^{[5][6]}. Researchers from Italy explored the characteristics of the landslide inventory from satellite SAR data, analysing landslide distribution and geomorphological features^[7].

Lidar is mainly adopted to obtain high-precision DEM, which is used to analyse deformation trends and characteristics of the landslide^[8]. Ventura used Lidar to discover tracking and evolution of complex active landslides in Southern Italy, identifying subtle ground deformations and landscape modifications due to mass movements and human activities^[9].

Although great improvements have been made in the study of UAV, InSAR and LiDAR application for landslide disasters monitoring, adaptability analysis for each and detailed strategies about combining these technologies to maximize the effectiveness are still insufficient. Further integration of these technologies to form a comprehensive and scientific monitoring, identification, and early warning system for landslide disasters, is an important research topic. This study made applied research about remote sensing technology in landslide disasters, which might improve the theory of landslide monitoring and provide technical support for monitoring, identification, early-warning and assessment for landslide disasters.

II. STUDY

In the process of this research project, we collected a large number of literature using UAV, LiDAR and InSAR applied in landslide disasters. From these studies, we would analyse the roles of UAV, LiDAR and InSAR in landslide identification, early warning, risk evaluation. We would also pay attention to the way how UAV, LiDAR and InSAR performs in landslide disasters application. As a result, the analysis results provide data support for this project.

A. Research on the application of UAV remote sensing technology in landslide disaster

UAV remote sensing technology mainly through high resolution image acquisition method, obtain the landslide area of close high resolution image, terrain change data, analyze the dynamic change of landslide and the influence of environmental factors, get the landslide area form characteristics, deformation trend and potential risk area of

accurate assessment conclusion, a large number of scholars made related research.

Nicola used UAV-DP remote sensing technology to study the landslide disaster in Ricasoli Village. Using a special camera mounted in the multi-rotor drone Saturn, they obtained

orthographic images from three surveys at the Ricasoli Village (Figure 1). Comparing these close high-resolution images, especially the multi-time photogrammetry performed on the northern slope of Ricasoli, determined the morphological characteristics of the landslide and its evolution over time at very high resolution^[10].

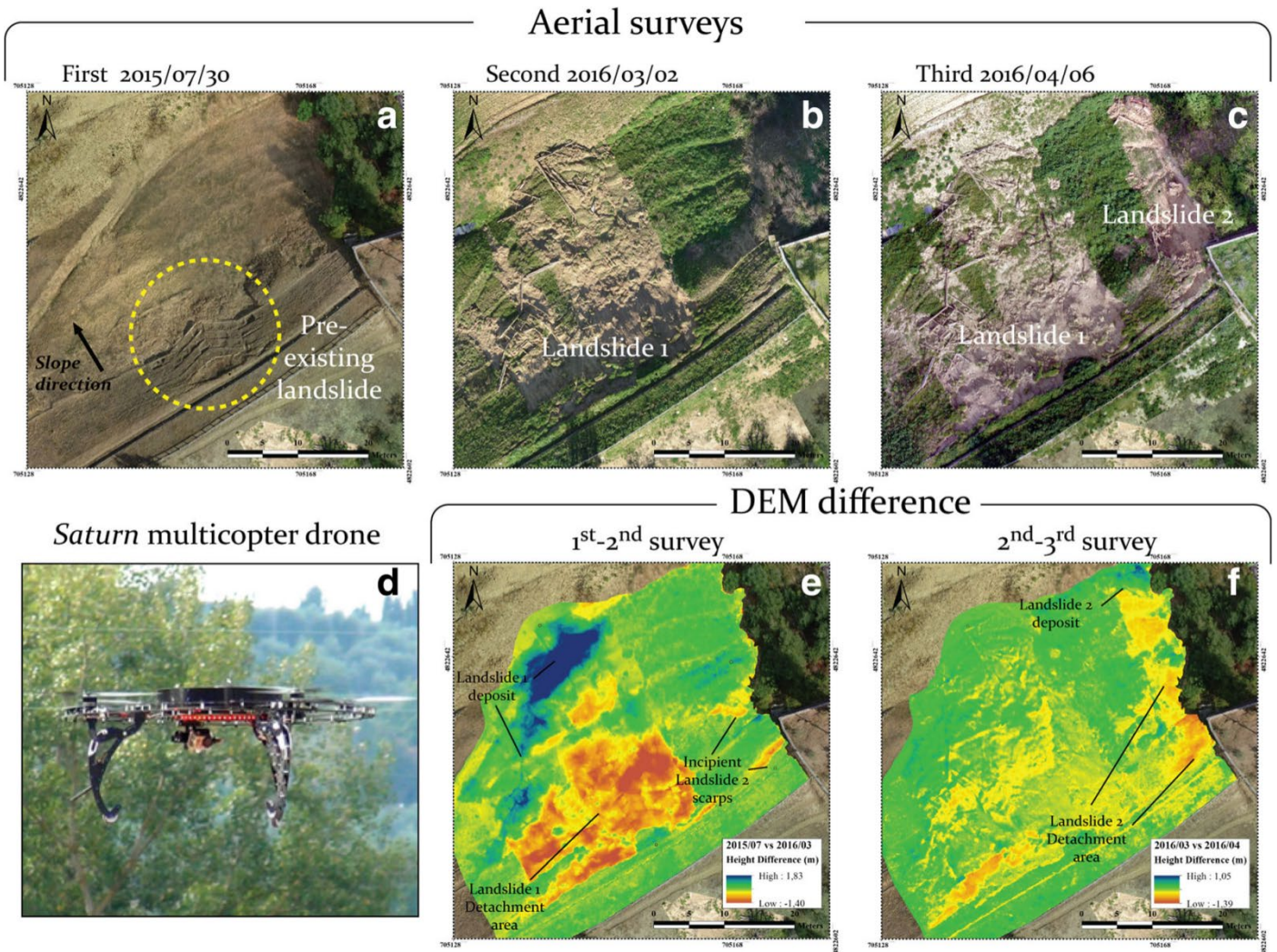


Figure 1. a, b and c Orthophotos acquired during the three surveys in Ricasoli village by means of a special camera mounted on the Saturn multicopter drone (d) and (e and f) the differences in height calculated using the high resolution DTMs. The main scarps and landslide features are detected and analyzed based on the results of the DTM comparison

Darren took pictures with the Canon camera carried by UAV, and obtained the image data monitored from 2012A to 2013A. After data processing and processing, an example of digital surface model (DSM) changes was obtained, highlighting the typical changes before and after the Huon valley landslide disaster^[11]. This study demonstrates that it is possible to generate accurate landslide DSM with unmanned aerial vehicles (UAV), and that the technology is reliable and reproducible, so that large time-series data sets can be collected regularly. However, the study also points out the limitation of using drone images to create 3D models, that is, no real surface digital elevation model (DEM) can be created, but only DSM. This is because the technology is based on passive optical

sensors and cannot penetrate the vegetation to find the real surface height like the LiDAR system.

Konstantinos demonstrated the high efficiency of UAV in obtaining fine topographic details and monitoring regional changes before and after landslide^[12]. During three field trips in Ano Kerasovo Village, Western Greece on February 8, 2021, 1 December 14, 2021 and 25 September 2022, they used drones to capture characteristic photos of the landslide cracks in the area. They also shot the same crack from the ground perspective. Konstantinos The team also used the photos to continuously monitor the extent of the landslide disaster in the area, and found that the extent of the landslide had increased by 200% and 70%, respectively. It is proved that the UAV can

continuously monitor the landslide activities and timely capture the surface deformation and landslide progress.

B. Application study of LiDAR technology in landslide disaster

LiDAR remote sensing technology mainly uses laser scanning and point cloud data acquisition methods to obtain high-precision terrain change, landslide volume, vegetation coverage and other data, LiDAR data performs well in analyzing the spatial deformation and terrain reconstruction results of landslide, and obtaining the accurate measurement of landslide regional deformation and the conclusion of landslide volume change.

Pellicani analyzed the landslide event in Montescaglioso Area, Italy^[13]. Through two LiDAR scans and point cloud data acquisition, DTM (Digital Terrain Model) from December 2013 and November 2016 were obtained and compared (Figure 2(a)) to obtain the main morphological changes (Figure 2(b)) within the landslide area and the elevation changes of the landslide before November 2016 (Figure 2(c)). It proves the ability of LiDAR remote sensing technology in constructing high-precision 3D terrain model of landslide area, especially the fine analysis of complex terrain.

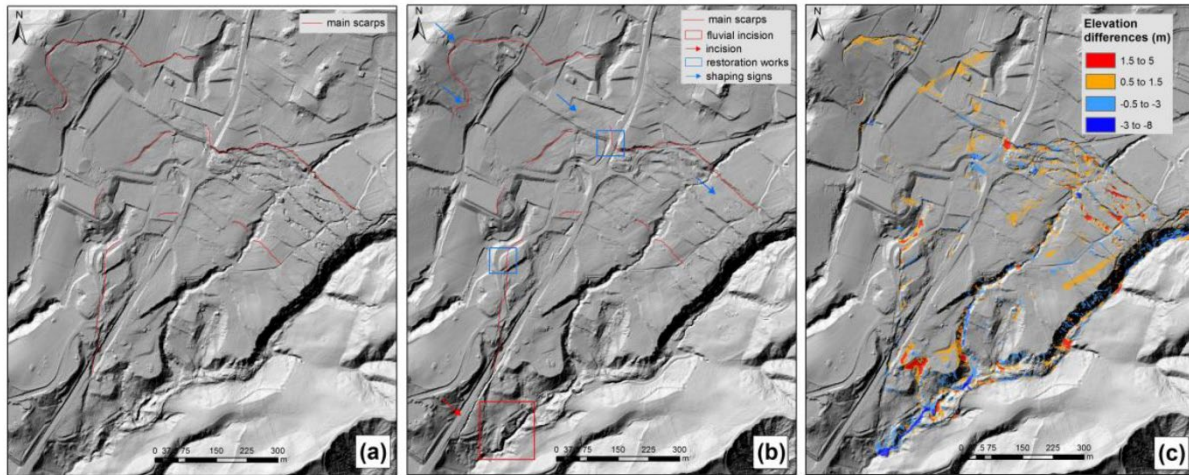


Figure 2. Comparison between two LiDAR DTMs performed post-event, in December 2013 (dec2013DTM) (a), and November 2016 (nov2016DTM), with the indication of the main morphological modifications within the landslide area (b), and elevation variations occurred in the landslide body until November 2016 (c).

Fernandez used LiDAR data obtained in southeast Spain to establish the DSM, do classified editing and obtain DTM data^[14]. By the older DTM data minus the newer DTM data, the Differential DTMs were got, from which the landslide disaster volume calculation and DTM profiles for e-ach time period was obtained. By calculating and comparing parameters identified from models, longitudinal sections and other evidence, we can assess the dimensions and morphology and determine trends regarding age, speed, activity, reproducibility and intensity based on published classifications.

Chen obtained LiDAR data in a landslide area in Jiangsu Province in China, which is combined with color enhanced images and 3D visual scene simulation to explain the overall morphological characteristics of the landslide, the differences of the texture from the surrounding images^[15]. As a result, 22 geological disasters were identified, 19 of which were finally confirmed as landslide geological disasters by field investigation, with the interpretation accuracy of 86.4%. With dense vegetation coverage, UAV and InSAR remote sensing technology is difficult to work in the area, but the airborne LiDAR technology has strong vegetation penetration ability. LiDAR technology was used for obtaining point cloud data to

generate high-resolution DEM for the topographic morphology after vegetation removal with real response.

C. InSAR Application study in landslide disaster

InSAR remote sensing technology mainly obtains the data of surface deformation and displacement rate through the image matching and difference processing methods, analyzes the surface displacement change in long time series and the dynamic behavior results of landslide, and obtains the conclusion of deformation monitoring and potential risk assessment of large-scale landslide area.

Zhao obtained SBAS-InSAR data in the Maiqu River landslide area in Tibet and analyzed the LOS deformation velocity field^[16]. As shown in Figure 3, a shows the ascending orbit of the landslide area and b shows the descending orbit of the landslide area. According to the above deformation monitoring results, the case delineated the strong deformation areas. The deformation activity was the most active the day when the landslide was about to happen. This study proves the application of InSAR technology in monitoring the high precision and wide coverage of a large range of surface deformation in a landslide area, especially in detecting small displacement and slow deformation.

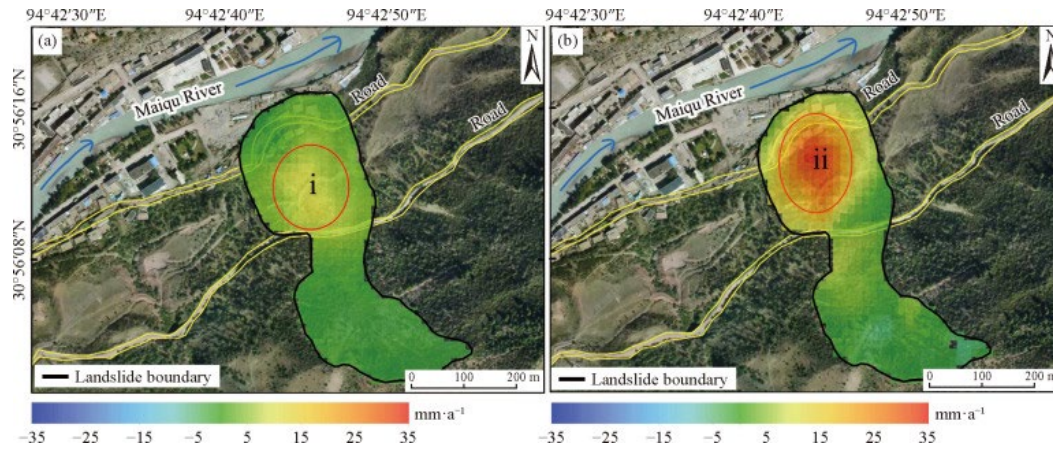


Figure 3. Deformation velocity fields along the LOS. a-Ascending orbit of the landslide area. b-Descending orbit of the landslide area. i and ii are areas with higher deformation velocity.

Carla obtained GB-InSAR data from 28 October 2016 to 30 June 2017 for Bosmatto landslide in the Italian Alps, and drew the cumulative deformation from the perspective of instrumental observation^[17]. The study defined the boundaries of the Bosmatto landslide and the debris flow area below the foot of the slope as shown in Figure 4. The applicability of InSAR to obtaining large-scale landslide data as well as difficult-to-reach alpine areas is highlighted.

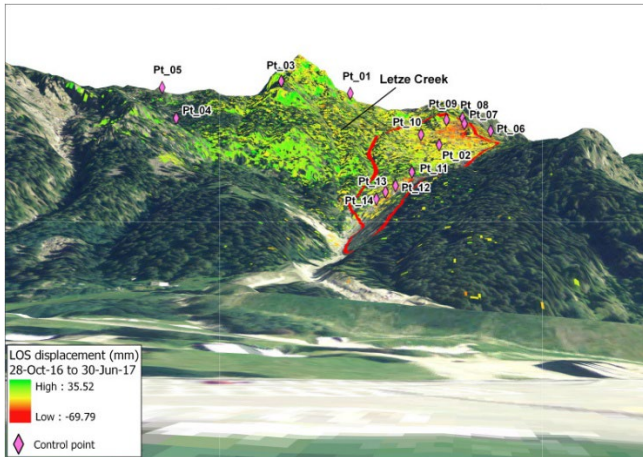


Figure 4. Cumulative deformation map produced by the GB-InSAR from 28 October 2016 to 30 June 2017 the boundaries of the Bosmatto landslide, as well as the debris flow source area below the toe.

D. Combinations of different techniques

Different combinations of remote sensing technology mainly through multi-source data fusion and comprehensive analysis methods, obtain high resolution images, three-dimensional terrain model, surface deformation monitoring data, analyze the comprehensive deformation trend, environmental change and potential risk results of landslide area, and get the conclusion of comprehensive assessment and accurate early warning of landslide disaster. Jiao applied the combination technology of UAV and InSAR to analyze the landslide that occurred in Guizhou Province in China^[18]. The Sentinel-1 descent trajectory was used to obtain data of 64 periods from 2 June 2017 to 22 July 2019. InSAR time series analysis resulted in the average surface deformation rate of the

landslide area. The results showed that there was a weak deformation signal of about 5 mm / year in the landslide area in the past two years. In this study, researchers conducted a field survey and acquired images at 14:00 PM on July 24, 2019 after the landslide. After analyzing the orthophoto image of the landslide disaster, researchers obtained the surface characteristics of the landslide and assessed the severity of the disaster. This study proved that InSAR technology can effectively detect surface deformation signals, and UAV aerial survey can quickly obtain ground morphology and texture information after a disaster. This solves the problem of rapid investigation of large-scale geological disasters from a regional perspective, and the combination of UAV and InSAR remote sensing technology has become a research hotspot for the application of new geological disaster technology.

Pellicani R integrated application of drones and LiDAR remote sensing technology in a landslide area in Italy, from December 21, 2013 to February 5, 2014^[19]. The drone survey, generated a high resolution DSM and orthophoto image respectively, which were used to draw the landslide form characteristics, to support the laser radar DTM in December 2013. As a result, it explained the landslide foot inaccessible key damage kinematics better. This study uses LiDAR remote sensing technology to generate DTM, which complements the DSM data acquired by UAV. The results of this study show that these two integrated methods are helpful to extract and evaluate the geomorphological features that indicate the destruction mechanism.

III. CONCLUSION

With the advantages of high flexibility, high resolution and low cost, and the ability of efficiently restoring 3D terrain model of the landslide area, the application of UAV in landslide disasters mainly focuses on close range monitoring, post-disaster assessment and data acquisition. However, there are also disadvantages such as restricted UAV flight regulations in some areas, the need for skilled operators, and the negative impact of vegetation on point clouds. With the advantages of high resolution, ability to penetrate vegetation and sensitivity to minor deformation, disadvantages of LiDAR include high equipment cost, complex data processing and limited coverage. The application of LiDAR is to identify landslides from large

spatial scale and determine their distribution and volume, and to determine the landslide boundary, which can provide scientific basis for quantitative analysis and early warning of different types of landslide disasters. With the ability to Monitor surface displacement, deformation rate and geological trends in landslide disasters, InSAR is mainly used in large-scale landslide monitoring, surface deformation detection and landslide risk assessment, including long time series deformation monitoring, potential landslide identification and pre-disaster warning. The advantages of InSAR technology lie in its high precision, wide coverage and all-weather monitoring capabilities, but it also has the disadvantages of complex data processing and great impact from vegetation and terrain, which leads to monitoring errors.

Therefore, UAV, LiDAR and InSAR technologies all have good application prospects in landslide disaster monitoring. Combining these three technologies, they can complement each other and give full play to the advantages of remote sensing technology. For example, for the early warning of landslide disasters, the combination of InSAR and UAV can seamlessly connect large-scale monitoring and local fine analysis; For the post-disaster recovery stage, the combination of LiDAR and UAV can accurately obtain 3D terrain change data and help with disaster assessment. Through the complementary of these technologies, the timeliness, accuracy and coverage of landslide disaster monitoring can be significantly improved, providing a more scientific and comprehensive solution for disaster prevention and reduction.

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