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Use of Uav-Based Photogrammetry for Landslide Inventory Mapping

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Abstract

Landslide inventory mapping is fundamental for hazard assessment, risk mitigation, and planning in mountainous regions. Conventional landslide mapping methods based on field surveys and satellite imagery often face limitations in spatial resolution, accessibility, and temporal frequency. Unmanned Aerial Vehicle (UAV)-based photogrammetry has emerged as a powerful tool offering high-resolution, flexible, and cost-effective data acquisition for detailed landslide inventory mapping. This paper presents an overview of UAV photogrammetry technology, including data acquisition, processing workflows, and interpretation techniques for landslide mapping. A case study from the Himalayan region demonstrates the integration of UAV-derived orthomosaics and digital terrain models (DTMs) to delineate landslide features and generate a comprehensive landslide inventory. The paper also includes a table summarizing UAV photogrammetry advantages compared to traditional methods. Challenges such as data processing complexity and regulatory constraints are discussed. The

study concludes that UAV photogrammetry substantially enhances landslide inventory accuracy and supports effective disaster management strategies.

***Keywords**: UAV Photogrammetry, Landslide Inventory, Orthomosaic, Digital Terrain Model, Remote Sensing, Hazard Mapping, Geomatics*

INTRODUCTION

Landslides are among the most frequent and devastating natural hazards in mountainous terrain, causing significant socio-economic losses. Accurate mapping of landslide occurrences—known as landslide inventory mapping—is critical for understanding spatial distribution, triggering factors, and susceptibility assessment.

Traditional mapping techniques rely heavily on field surveys and satellite or aerial imagery. Field surveys provide detailed but spatially limited data and are labor-intensive, while satellite imagery offers wide coverage but often lacks adequate spatial and temporal resolution for small or recent landslides.

Recent advancements in Unmanned Aerial Vehicle (UAV) technology combined with photogrammetry have enabled generation of high-resolution geospatial data over inaccessible terrains. This study focuses on using UAV-based photogrammetry to improve landslide inventory mapping and discusses its workflows, applications, and benefits.

UAV PHOTOGRAMMETRY: TECHNOLOGY AND WORKFLOW

UAV photogrammetry involves capturing multiple overlapping images of a terrain using drones equipped with high-resolution cameras. These images are processed using specialized software to produce georeferenced products such as orthomosaics and digital terrain models (DTMs).

- **Data Acquisition:** Flight planning is essential to ensure sufficient image overlap (typically 70–80%) and coverage. Altitude, camera parameters, and lighting conditions affect image quality.
- **Image Processing:** Structure-from-Motion (SfM) algorithms align images, generate point clouds, and reconstruct 3D surface models. Georeferencing is done using ground control points (GCPs) or onboard GPS data.

- **Product Generation:** Outputs include high-resolution orthomosaics—geometrically corrected aerial images—and DTMs that capture surface elevation, critical for detecting landslide scarps and deposits.
- **Interpretation:** Visual analysis and automated classification techniques identify landslide boundaries, types, and affected areas.

ADVANTAGES OF UAV PHOTOGRAMMETRY FOR LANDSLIDE MAPPING

Advantage	Description	Benefit for Landslide Mapping
High Spatial Resolution	UAVs can capture images with centimeter-level resolution	Detects small and recent landslides missed in satellite data
Flexible Deployment	UAVs can be deployed rapidly and repeatedly	Enables temporal monitoring and post-event assessments
Cost-Effective	Lower operational costs compared to manned aerial surveys	Suitable for frequent monitoring and large area coverage
Accessibility	UAVs can access remote and hazardous areas	Enhances data collection in inaccessible terrain
Multi-Modal Data	Integration with other sensors (thermal, multispectral) possible	Supports comprehensive hazard characterization

Table 1: Advantages of UAV Photogrammetry for Landslide Inventory Mapping

CASE STUDY: UAV-BASED LANDSLIDE MAPPING IN THE HIMALAYAN REGION

The study area is a 10 km² hilly terrain in Uttarakhand, India, characterized by active landslides due to steep slopes, heavy monsoon rains, and geological fragility.

- **Data Collection:** A DJI Phantom 4 Pro UAV was flown over the site at an altitude of 120 meters with 80% front and side overlap.
- **Processing:** Images were processed using Agisoft Metashape software to generate a 5 cm spatial resolution orthomosaic and a 10 cm resolution digital terrain model.

- **Results:** Several landslide features, including scarps, toe deposits, and tension cracks, were delineated precisely. Newly formed landslides from the previous monsoon were mapped, which were not clearly visible in Sentinel-2 satellite imagery.
- **Integration:** The inventory was integrated with GIS data layers for slope, aspect, and land use to analyze triggering factors.

DISCUSSION

UAV photogrammetry demonstrates superior capability in detecting landslides of varying scales with excellent spatial detail. It facilitates rapid and repeated surveys essential for temporal change detection and hazard monitoring.

Despite its advantages, challenges exist:

- **Data Processing Demands:** Processing large image datasets requires high computational resources and expertise.
- **Regulatory Restrictions:** UAV operations are subject to airspace regulations, requiring permissions that may delay deployment.
- **Weather Dependency:** UAV flights are limited by adverse weather conditions like rain and strong winds.
- **Ground Control Points:** Accurate georeferencing requires ground control points, which may be difficult to establish in rugged terrain.

Future directions include integrating UAV data with satellite remote sensing and machine learning-based automated landslide detection to improve efficiency.

CONCLUSION

The application of UAV-based photogrammetry significantly advances landslide inventory mapping by providing high-resolution, flexible, and cost-effective data acquisition. It enables detailed mapping of landslide features that are critical for hazard assessment and risk management in mountainous regions. Integration with GIS enhances spatial analysis of landslide susceptibility. Overcoming current challenges through technological and regulatory improvements will expand UAV photogrammetry's role in geohazard monitoring and disaster resilience planning.

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