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UAV-based rockfall hazard detection via roughness analysis in Karaköprü, Şanlıurfa using photogrammetric point clouds

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Abstract

This study focuses on rockfall hazard detection in urban terrain, particularly the Karaköprü district of Şanlıurfa, utilizing UAV-based photogrammetric dense point cloud analysis. The research introduces an innovative approach that combines advanced geospatial technology and roughness analysis to identify and assess rocks situated above ground surfaces, thereby mitigating potential risks to transportation routes and buildings. The methodology involves quantifying surface irregularity using roughness analysis, where the distance between points and their best-fitting planes is computed based on a carefully selected kernel size. The results demonstrate that this approach effectively marks rocks across the study area, albeit with considerations for potential misclassifications. The dataset is derived from a photogrammetric UAV flight, yielding over 77 million three-dimensional points, while manual examination informs the choice of a 30 cm kernel size, later applied to the entire dataset. In summary, this research showcases the potential of UAV-based photogrammetric point cloud analysis to enhance urban safety and infrastructure resilience in sloping terrains, emphasizing the significance of prior knowledge, kernel size selection, and point density for achieving accurate and reliable results. This approach holds promise for safeguarding urban populations and critical infrastructure in similar urban and geological contexts.

Introduction

Urban areas often encompass diverse landscapes, and one such terrain feature of concern is sloping ground, which may host scattered rocks of varying sizes [1]. These rocks, if not appropriately identified and managed, can pose significant risks to both the safety of city inhabitants and the integrity of surrounding infrastructure [2]. The challenge lies not only in detecting these potential hazards but also in understanding their spatial distribution, size, and degree of exposure above the ground surface [3]. In this context, the integration of advanced geospatial technologies presents a promising solution [4]. Unmanned Aerial Vehicles (UAVs), equipped with high-resolution cameras, provide an efficient means to capture detailed aerial imagery of urban slopes and their surroundings. When processed through photogrammetry, these images can generate dense point clouds, offering rich three-dimensional representations of the terrain and its features [5].

One crucial geometric attribute that becomes instrumental in assessing the danger posed by rocks on sloping urban terrain is roughness. Roughness, in this context, characterizes the irregularity and unevenness of the ground surface. When applied to a dense point cloud, roughness analysis unveils valuable insights into the topography and protrusions above the surface. It enables the differentiation of rocks from the surrounding terrain and assesses their elevation above the ground plane.

The study will take place in Karaköprü district of Şanlıurfa province, a region known for its unique geological characteristics and urban development challenges. By employing this technique, our objective is to identify and evaluate rocks that are situated above the ground surface in this specific urban landscape, thereby posing potential hazards to urban transportation routes and nearby multi-story buildings [3]. The integration of this geospatial approach not only aids in rock hazard detection but also provides crucial information for urban planners and safety authorities to devise strategic mitigation measures [5].

The remainder of this research delves into the methodology employed for roughness analysis, the detection and assessment of above-surface rocks, and the implications for urban safety and infrastructure resilience within the Karaköprü district. By harnessing the power of modern geospatial technologies, we endeavor to enhance the proactive management of rockfall risks in this specific urban setting, contributing to the safety and well-being of city dwellers and the preservation of urban infrastructure.

Material and Method

Roughness

Roughness estimation is a fundamental aspect of three-dimensional point cloud analysis. It involves a straightforward calculation for each point in the cloud, where the 'roughness' value is determined by the distance between that point and the best-fitting plane, computed based on its nearest neighbors [6]. The 'kernel' refers to the neighborhood radius, defining the region around each point from which neighboring points are considered. Within this neighborhood, the orthogonal distance to the best-fit plane is calculated to assess roughness [7]. This calculation relies on differences in height between the central point and the average height of its neighboring points, all computed along a specified 'vertical' orientation. This approach provides a quantitative measure of surface irregularity and is invaluable in numerous applications across various domains, aiding in tasks such as hazard detection, structural analysis, and surface quality evaluation.

Point cloud generation

Obtaining a UAV-based photogrammetric dense point cloud often involves the integration of Structure-from-Motion (SfM) techniques, harnessing the capabilities of Unmanned Aerial Vehicles (UAVs) equipped with high-resolution cameras [8]. In this process, the UAV is deployed to capture a series of overlapping aerial images from various angles and altitudes over the target area. These images serve as the primary data source. Through the application of SfM algorithms, these images are meticulously analyzed and processed to reconstruct a dense point cloud. SfM techniques employ precise triangulation methods to calculate the three-dimensional coordinates of points on the Earth's surface, based on their appearances in multiple images. These computed 3D coordinates collectively form the dense point cloud, where each point corresponds to a specific location in the surveyed area [9]. This point cloud delivers an exceptionally detailed and accurate representation of the terrain or objects within the surveyed region. It serves as a foundational resource for a wide range of applications, including 3D modeling, topographic mapping, land surveying, environmental monitoring, and beyond.

Results

Within the scope of the study, a photogrammetric drone flight was carried out in the relevant region. 262 aerial photographs with 80% overlap were obtained with the flight made with Mavic 2 Pro from a height of 70m. With the processing of the data, more than 77 million three-dimensional point data were obtained (Figure 1).

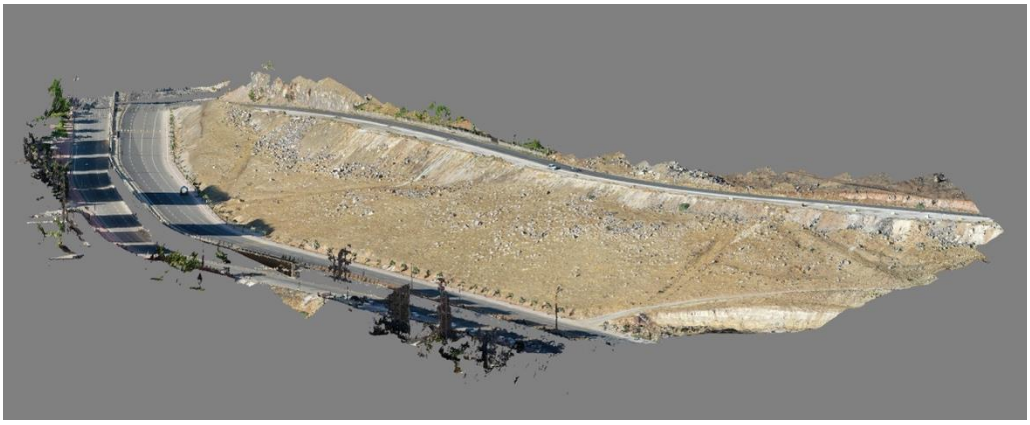

Figure 1. Point cloud of the study area

The dataset underwent an initial manual examination in a part of study area, during which a meticulous search was conducted to identify and catalog rock sizes. This preliminary step is essential to facilitate subsequent roughness analysis. After careful consideration, a kernel size of 30 cm was ultimately selected as the most suitable parameter for the analysis in a part of study area. A detailed view of the obtained result is presented in Figure 2.

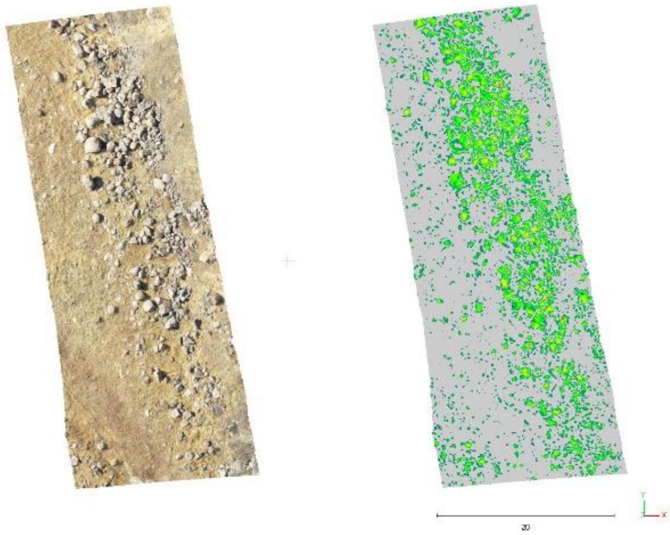

Figure 2. Close view of the results

As the kernel size provided valuable results within a limited area, these same parameters were extended to the entire dataset. The outcome marked points corresponding to rocks across the entire study area (Figure 3).

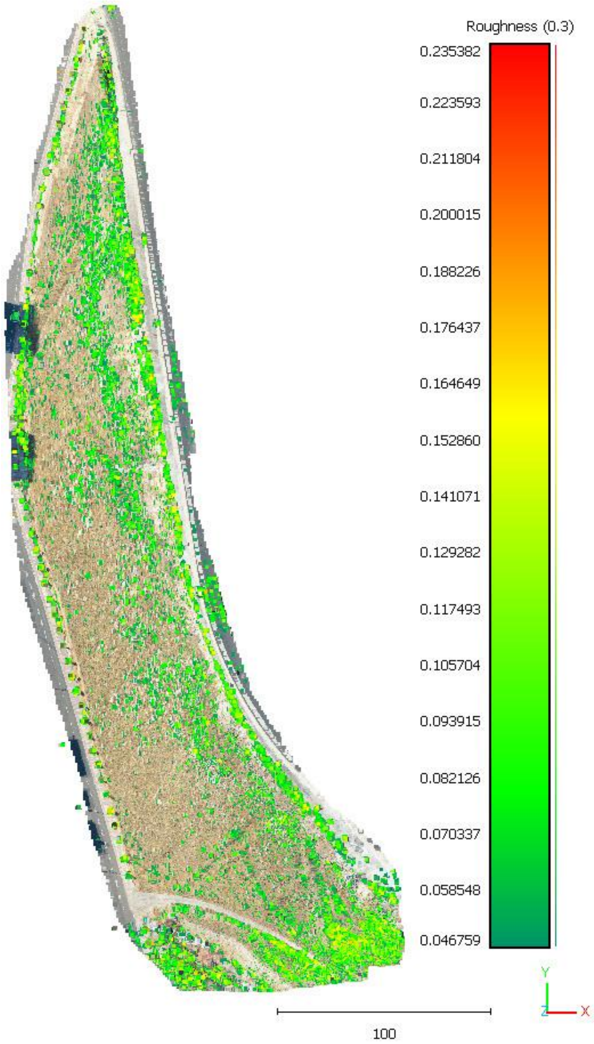

Figure 3. Roughness based rocks

However, it's worth noting that some of these points may also pertain to bushes. To mitigate the potential for such misclassifications, it may be necessary to either narrow the field of analysis or preprocess the data to remove unrelated objects.

Discussion

When conducting roughness analysis, having prior knowledge about the region can prove highly advantageous. This is particularly relevant due to the influence of kernel size selection on the potential detection of rocks, as certain rocks may be only partially or entirely overlooked based on this parameter. Therefore, having at least a general understanding of the size of rocks within the area becomes invaluable. Additionally, point density plays a critical role in this process. Ensuring that the point density within the kernel is sufficient is essential for the rocks to be effectively detected and integrated into the analysis. However, it's important to note that providing an exact point density ratio is challenging, as it can vary substantially depending on the specific dataset and workspace characteristics.

Conclusion

This study employed UAV-based photogrammetric dense point cloud analysis for rock fall hazard detection in the Karaköprü district of Şanlıurfa. The methodology centered on roughness analysis, quantifying surface irregularity through the distance between points and their best-fitting planes using a selected kernel size. The process successfully marked rocks in the study area, with attention to potential misclassifications. The dataset was obtained through a photogrammetric drone flight, producing over 77 million three-dimensional points. Manual examination informed the choice of a 30 cm kernel size, applied to the entire dataset. In summary, this research showcases the effectiveness of UAV-based photogrammetry and roughness analysis in urban rock fall hazard detection. It underscores the importance of prior knowledge, kernel size selection, and point density consideration for accurate results. This approach enhances urban safety and infrastructure resilience, with potential applications in similar urban contexts.

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