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Monitoring 3D areal displacements by a new methodology and software using UAV photogrammetry

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ABSTRACT

Nowadays, a lot of different geodetic methods based on terrestrial and remote sensing (Global Navigation Satellite System-GNSS, Total Station, Lidar, ground-based radar, Synthetic-aperture radar-SAR, etc.) are used in three-dimensional (3D) monitoring of mass movements. In recent years, Unmanned Aerial Vehicle (UAV) photogrammetry has been used in monitoring large mass movements, especially landslides. In this study, the traceability of 3D areal displacements in a dump site, which is jointly used by three different open marble pits, with a new methodology based on a UAV which has advantages compared to other methods was investigated, and the results of the application were revealed by developing software specific to the methodology. In this context, a deformation network consisting of 46 specially designed plates was established as to include the area and dump benches by paying attention not to being in the locations where new dumps were made since surface topography and morphology changed continuously due to new dumps, and 3-periodic UAV flights were performed. As a result of these flights, periodic orthomosaics and digital elevation models (DEM) were produced. The special plates placed in the field were automatically detected with the software developed and 3-D coordinates of each plate were obtained. From these coordinates obtained, the velocity values of the points were calculated using the Kalman filtering technique. The velocity values obtained by the GNSS method at the same points were used to verify the results of UAV photogrammetry and to reveal its performance. Whether the velocity values obtained by the GNSS and UAV methods could be considered as equal was determined by statistical analyses (t-test, f-test, RMSE, and VAF). As a result of these analyses, it was found out that significant velocity values greater than 1.5 × GSD (Ground Sample Distance) obtained from GNSS could be determined successfully with UAV. Furthermore, interpolation maps were generated from GNSS and UAV velocity values to compare areal displacements, and it was observed that north (n), east (e), height (up) components of maps were compatible with the correlation values of 0.92, 0.75, 0.87, respectively.

1. Introduction

In this study, the performance and sensitivity of UAV photogrammetry in three-dimensional (3D) monitoring of mass movements were investigated. With the use of GNSS technology, which is one of the most common methods used to monitor geodetic displacements nowadays, 3D displacements of checkpoints can be produced directly, while a large number of checkpoints are needed to determine areal displacements. Since the increase in the number of points increases the time requirement and cost, the monitoring of displacements by the GNSS method may not meet expectations especially in projects with limited budget and time. In the Interferometric Synthetic Aperture Radar (InSAR) technique, which is another method, 3D displacements cannot be monitored with one-dimensional velocity data in the direction of Line of Sight (LOS) it produces although the number of points is high. From satellite images, displacements below the meter level cannot be monitored since the existing pixel resolutions are low. The data and images of Airborne Laser Imaging Detection and Ranging (LiDAR) have high positioning accuracy. However, the extremely high cost associated with the use of aircraft and its time-consuming nature makes this strategy an impractical solution, especially for investigations of small areas (Al-Rawabdeh et al., 2016). Unmanned Aerial Vehicle (UAV) photogrammetry is a method that can meet the needs with respect to the production of geodetic points with 3D velocity information and the sufficiency of the number of points. UAV photogrammetry incorporates the GCPs to georeference a reconstructed UAV-based point cloud or it uses the Real-Time Kinematic (RTK)-based camera exposure stations, which is called a direct georeferencing approach instead of

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