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Accuracy of direct georeferencing strategies to monitor geomorphological features

Álvaro Gómez-Gutiérrez[1], Manuel Sánchez-Fernández[2], José Juan de Sanjosé-Blasco[2], and Francisco Lavado-Contador
[1]Instituto Universitario de Investigación en Desarrollo Territorial Sostenible, Grupo de Investigación Geoambiental, Universidad de Extremadura, Avda. de la Universidad s/n 10003 Cáceres, España (alvgo@unex.es)
[2]Instituto Universitario de Investigación en Desarrollo Territorial Sostenible, Grupo de Investigación Ingeniería, Territorio y Patrimonio, Universidad de Extremadura, 10003 Cáceres, España

Geomorphic systems face significant changes of climate, land uses, vegetation cover and socio-demographic characteristics. In this context, the accurate monitoring of geomorphological features may be a relevant tool to understand the consequences and the risks of these changes. At the same time, monitoring some geomorphic systems (for instance a coastal cliff) may be challenging, difficult and dangerous. The direct georeferencing techniques, which do not require acquiring Ground Control Points (GCP), recently integrated into new platforms (mainly Unmanned Aerial Systems or UAS) and sensors (photographic or laser) facilitate this task. Here we test the accuracy of direct georeferencing approaches for two UAS: a DJI Phantom 4RTK (P4) and a MD4-1000 LIDAR. Two flights were carried out to capture images with the P4 over a beach and a coastal cliff in Cantabria (N Spain): a) in Real Time Kinematic (RTK) mode receiving NTRIP corrections and b) without real time corrections to later process the data using a Post Processing Kinematic (PPK) approach with simultaneously registered data at permanent GNSS stations. The PPK approach for the P4 dataset was carried out using Redcatch software and three permanent stations located at different distances of the study area to analyse the influence of the baseline. The P4 datasets were processed by the Pix4Dmapper Pro photogrammetric software to produce 3D models. The same study area was surveyed by the MD4-1000 LIDAR UAS that performs in PPK mode and produces a 3D model. The MD4-1000 LIDAR dataset was processed using PosPac UAV and mdLIDAR processing software packages. Two datasets were used to test the accuracy of the resulting 3D models: a set of 18 check control points established in the study area and surveyed using a GNSS instrument in RTK mode and a 3D model surveyed by a Terrestrial Laser Scanner placed at 5 locations ($23.4 \cdot 10^6$ points with a registration error of 7 mm).

The P4 RTK approach showed a Root Mean Square Error (RMSE) for the Z coordinate of 0.12 m against 0.02 m obtained for the PPK approach. The MD4-1000 LIDAR showed a RMSE for the XY coordinates of 0.03 m and 0.06 for the Z coordinate. These figures were corroborated by the 3D distances between each resulting model and the TLS 3D model. In terms of point density and coverage the P4 resulting point clouds outperformed that obtained by the MD4-1000 LIDAR system, except in vegetated surfaces, where the photogrammetric technique completely failed to reconstruct the surface (i.e. to calibrate the images). These results and figures may be useful for geomorphologists and surveyors interested on monitoring features without the need for GCPs.