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Improving 3D models of landforms produced by SfM techniques using visibility analysis

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Structure-from-Motion photogrammetry (SfM) is one of the most recent innovations in Earth Sciences and has been successfully applied to produce 2.5D, 3D and 4D models in Geomorphology. Several factors influence the error in SfM approaches (camera-to-ground distance, camera-sensor system parameters, image network geometry, image matching performance, terrain type, lighting conditions and referencing methods) and their contribution usually depends on the characteristics of each individual survey.

In the case of image network geometry it is not yet possible to determine a priori the optimal camera locations and orientations for a specific survey site. Topography and illumination conditions are unique for every survey and represent an important and unknown contribution to the quality of the 3D resulting models.

Here, we present a strategy to minimize the occlusion produced by topography and determine optimal camera locations for image acquisition. Viewshed algorithms implemented within a Geographical Information System (GIS) are used for this purpose. The analysis is feed by a Digital Elevation Model (DEM), camera locations and sensor size. The DEM could be a preliminary DEM obtained by SfM or a pre-existing DEM. In the same way, camera locations and sensor size can be camera coordinates registered in the field or simulated camera locations (in order to estimate the visibility of each camera).

One terrestrial (Veleta rock glacier) and two aerial (Araguás and Valpalmas badlands) datasets were used to analyze differences between SfM models produced using 1) a dataset overloaded with photos, 2) photos selected using the viewshed analysis and 3) a dataset acquired following conventional schemes for sub-sampling images. The resulting models were tested in terms of processing time, point density, coverage, georeferencing errors, distance to benchmark point clouds (acquired by means of Terrestrial Laser Scanner; TLS) and DEMs (elaborated using the TLS data).

Point clouds obtained using the viewshed analysis were denser for the three datasets. For the terrestrial case, the point cloud produced using the photos with the highest visibility were notably denser with 40% more points than those created using datasets acquired and processed following conventional strategies. For the aerial datasets, differences were smaller with 3.8% and 1.1% more points in the clouds produced using the viewshed criteria. Regarding the accuracy of points in each cloud it was similar for the different approaches. However, the existence of larger no data zones in the conventional approach (without viewshed criteria) resulted in DEMs with higher differences (i.e. larger Mean Absolute Errors: MAE) with benchmark models (TLS). At the same time, DEMs produced using the viewshed criteria showed lower MAEs than the conventional dataset and similar to the dataset overloaded of pictures. Additionally, the processing time of the datasets that used viewshed criteria was much shorter (from 43% to 63%) than the datasets overloaded of pictures.

According to these findings, integrating visibility analysis in SfM workflows may be helpful to produce denser point clouds, elaborate more accurate DEMs and reduce processing time notably. Future research steps focus on designing specific tools within GIS software to improve photo acquisition in SfM surveys.