Structure from motion and multiview stereo (SfM-MVS) in geomorphometry

UCHIYAMA, Shoichiro[1]* ; INOUE, Hiroshi[1] ; SUZUKI, Hinako[1]

[1]National Research Institute for Earth Science and Disaster Prevention (NIED)

Software that unifies structure from motion (SfM) and multiview stereo (MVS) is currently in use. Hence, the construction of three-dimensional models and digital elevation models (DEMs) has been readily achieved at low cost using PCs. Both SfM and MVS are technologies developed in the computer vision field. SfM refers to the process of estimating three-dimensional structures from two-dimensional images. MVS generates three-dimensional models as point clouds. Digital cameras images or aerial photos are used in the calculations and three-dimensional models are produced. To date, DEMs are derived by conventional photogrammetry or LiDAR. However, photogrammetry requires special software, experience, and extensive manual measurement of ground control points (GCPs); furthermore, LiDAR is expensive. To use SfM?MVS in geomorphometry, data accuracy is an issue as well as the precision of GCPs; issues that have attracted the attention of many researchers. In this study, we discuss three examples of the application of SfM?MVS to geomorphometry.

First, we present the case of a detailed topographic map in Izu-Oshima, Tokyo, where a large-scale slope failure occurred before dawn on October 16, 2013, owing to the heavy rains of Wipha typhoon. To obtain a detailed DEM of the damaged slope, we took vertical photographs by UAV and generated a DEM by using SfM?MVS. As a result, we produced a topographic map with a 0.5 m contour interval. The topography was well reproduced and well compared to the LiDAR map with a resolution of 5 m provided by the Geographical Survey Institute.

Second, we created a topographic map using a vertical movie taken by UAV and SfM?MVS processing. A movie has few total pixels per picture compared with a still picture. A 4K-resolution movie has approximately 8 million pixels, whereas a high-definition (HD) movie has approximately 2 million. Moreover, because of lens distortion corrections when a wide-angle lens is used, the pixels that can be used in the calculations decrease. However, there is noise owing to compression compared with a still picture. Thus, the results are not as good as time-lapse photography using still pictures. UAV has also the risk of crashing, thus, it is wise not to use expensive equipment. Cheap cameras without time-lapse function are also available for SfM?MVS. Moreover, old video data can be used to obtain DEMs.

Finally, third, we obtained DEMs from scanning aerial photos. In Japan, the aerial photo archives are currently exceeding 1 million sheets. Therefore, if accurate DEMs are obtained from aerial photos, comparisons are possible and changes over time can be identified. We examined color aerial photographs taken in 1978 and 2012 at downstream area of Nakama River, Iriomote island, Okinawa Prefecture. The aerial photos comprised scans of 23-cm one-side analog photographs (1978) and digital aviation camera data (2012). The data were scanned at a resolution of approximately 1,270 dpi and the total number of pixels per image was approximately 120 million pixels. The resolution of the digital aviation camera photographs was 9,920 x 14,430 pixels. We also processed them by using SfM?MVS and we obtained DEMs with ground resolution of 0.3 m. We used the processed photographs to evaluate the vegetation damage caused by the 2006 and 2007 typhoons.

We show that SfM?MVS can be used in geomorphometry taking advantage of archived records. We anticipate that this methodology will be used more in the future.

Keywords: Structure from Motion (SfM), multi-view stereo (MVS), geomorphometry, topographic map, movie, aerial photograph

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