HTT08-01   Room:415   Time:April 29 16:15-16:30

Estimation of ground displacements by Geomorphic Image Analysis, using multi-temporal LiDAR DEM

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In the previous study, authors developed the new method which applies the technique of image matching analysis with high resolution DEM over difference times, to estimate the minute ground displacement of less than 1m order quantitatively and easily (Mukoyama et al., 2009 and Mukoyama, 2011). The present study shows the results of subsequent case studies to measure crustal movement, earthquake fault displacements, and the movement of landslides. Additionally we will show the results of comparative verification with some field observations by GNSS stations.

There are two approaches for the calculation of ground displacements from geomorphic point cloud data which is acquirable by temporal high-resolution LiDAR survey. Iterative Closest Point (ICP) is the method for 3D-matching by iterative calculation to find the positions which minimize the difference of coordinate values between paired points in the search area. The other approach is the combined methods of 2D-image measurement for estimation of horizontal component and point cloud calculation for vertical component. These two approaches share common process for finding the best position to minimize the difference between points belong the small search window in the temporal data. For this study, we applied the latter approach which is based on the technique of digital image matching analysis using geomorphic image made from grid data of digital elevation model (DEM).

In this method, the existing Particle Image Velocimetry (PIV) algorithm was used for the 2-dimentional image matching. And orthographic slope angle image was used as measurable digital geomorphic image. Although PIV method has been developed generally for fluid analysis, grayscale gradient slope angle image is suitable for PIV analysis as it utilizes the validity of random distribution image of particles in fluid. In order to estimate vertical displacements, the vertical component is available by interpolation of the elevation values of DEM around endpoints of the calculated vector.

In recent study, above-mentioned method was applied to measure ground displacement due to the Great Japan Earthquake in 2011. In the region where liquefaction had damaged the reclaimed land, 10-50cm of lateral displacements were observed in some divided small areas, and seaward deformation of sheet-pile revetment by lateral movement was also observed at the spot on the seaside. After the earthquake, northern part of Japanese Islands moved eastward 6m or less. Verification analysis was conducted in order to compare between the results of Geomorphic Image matching Analysis and GPS observations in the region where temporal LiDAR data and GPS station data was available. Generally both of the results were corresponding with a high correlativity. In the additional study, verification analysis of landslide movement was conducted with GPS observation data; and both of the results were corresponding well with small error range.

The displacement measurement technique by high-definition digital geomorphic image made from high-resolution point cloud survey is effective and simple method, which has the accuracy of about 1/10 pixels or more. It is thought that this method is practicable for measurement of the movement of landslides, earthquake faults, etc.

References
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Keywords: DEM, LiDAR, DEMs of Difference, image matching analysis

Landslide surface deformation detection by Iwate-Miyagi Nairiku earthquake using 2.5D analysis on SAR interferometry

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We have already reported landslide surface deformation by 2008 Iwate-Miyagi Nairiku earthquake using Synthetic Aperture Radar interferometry (InSAR) images. In this study, to detect the landslide surface deformation quantitatively in the SE area of Mt.Kurikoma, report the result of 2.5D analysis on the images (i.e., combination of the images observed from ascending and descending orbits).

Keywords: SAR, interferometry, earthquake, landslide, 2.5D analysis

HTT08-03 Room:415 Time:April 29 16:45-17:00

Evaluation of topographic measurements using UAV- and ground-based SfM and TLS: A case study at a rocky coast bench

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Recent advances in measurement methodologies of high-resolution topographic data, including terrestrial laser scanning (TLS), structure from motion photogrammetry (SfM) on unmanned aerial vehicle (UAV) and ground-based SfM, enabled detailed investigations of land surface morphology in terms of morphometry and processes. Although such advanced methodologies are becoming widely applied in geomorphological studies, the nature of such data including error estimates needs to be carefully assessed when being applied in geomorphological researches. In this study we examine similarities and differences among three methods for the topographic data acquisition at a local scale (~100 m): UAV-SfM, ground-based SfM and TLS. The study site is a coastal bench at Aburatsubo in Miura Peninsula, central Japan, which suffers from intermittent uplift by large earthquakes such as the 1923 Kanto earthquake (M 7.9). UAV-based SfM was performed from higher altitude (ca. 30 m) to lower (ca. 10 m) using a quadcopter on which a digital camera with single-focus lens is mounted. We also used a digital camera mounted on a 4-m long pole for ground-based SfM. TLS measurement was carried out using a short-range scanner from 6 scan positions. Also, coordinates of three benchmarks on ground that are commonly used in all the methods were measured using global navigation satellite system (GNSS) capable of receiving dual radiowaves and post-processing based on career-phase correction with an accuracy of centimeters. The comparisons of the point clouds and digital elevation models (DEMs) obtained by three different methods indicate that 1) SfM-based data shows good accuracies in and around, but significant discrepancies outside of the benchmarks, 2) TLS sometimes give significant lack of data in shadow areas, and 3) data quality of SfM partly depends on the altitude of its platform (either UAV and pole). These characteristics we assessed will give insights into the selection of appropriate methodology for different purposes of geomorphological surveys.

Keywords: rocky coast, structure from motion, terrestrial laser scanning, point cloud, digital elevation model, accuracy

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Comparative analysis of knickpoint extraction using semi-automatic and automatic methods

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Extraction of knickpoints (or knickzones) from a DEM has gained immense significance in studies of fluvial erosion and/or slope failures because of their geomorphological significance. Previously, knickpoint extraction from a DEM included a vector-based semi-automatic, but somewhat tedious and time-consuming data processing because GIS and spreadsheet software were separately used. Raster-based Python scripting, developed in our study and deployed in the form of a toolset, can automate the processes making the extraction of knickpoints automatically, fast and user friendly. Both the methods are based on the assumption that the slope gradient along a bedrock river changes with change in measurement length and any locally steep segment of the riverbed may then be considered a knickpoint. The relative steepness index R_d or the rate of decrease of gradient along the measurement length is calculated by solving a linear regression equation, $G_d = ad + b$ where, G_d (m m^{-1}) is the stream gradient at a point and d (m) is the measure distance, while a and b are coefficients and $-a$ is regarded as R_d which means the rate of gradient decrease with increasing d. In the former method G_d is measured at the mid-point of a segment of variable length d along longitudinal stream profiles where; $G_d = (e_1 - e_2) / d$ where, e_1 and e_2 are elevations at both ends of the segment, thereby analyzing both the upstream and the downstream segments along a stream. The automated Python processing, however, follows a slightly different approach from the one previously used and thus requires a comparative analysis of the two prior to its future use. The methods differ in the calculation of the stream gradient G_d; the former employs both the upstream and downstream elevations $d/2$ apart, whereas the latter uses the elevation at the point and d downstream. In this study, the Python toolset has been applied to a 10-m DEM of a mountainous region near Mount Ontake in the Northern Japanese Alps. The results were then compared and validated with the previous method. In order to study the fluvial characteristics of the knickpoints, analysis were confined only to the stream locations, the results of which provide insights into morphological developments of the watersheds.

Keywords: automatic extraction, DEM, knickpoints, Python

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

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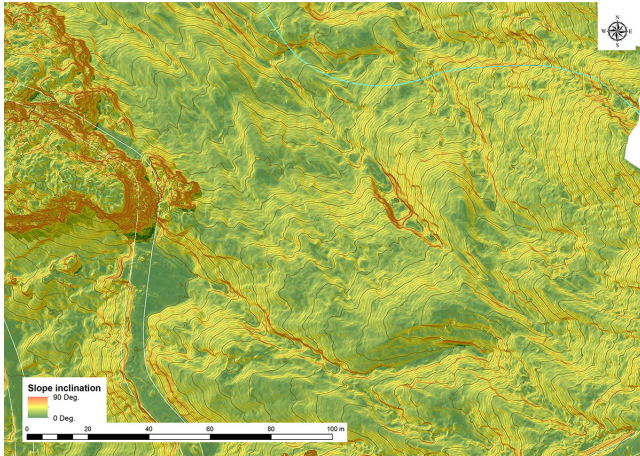
We show that SfM?MVS can be used in geomorphometry taking advantage of archived records. We anticipate that this methodology will be used more in the future.

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

Terrestrial laser scanning approach on quantification of weathering depth of sandstone blocks in a coastal environment

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Weathering in a coastal environment often causes degradation of artificial constructions if they are composed of weathering-prone materials including natural rocks and cements. Conservations of the vulnerability of such construction materials to weathering processes are thus important for their maintenance. Point to point, or cross-sectional measurements using scale bars have often been effective in describing the degree of weathering of such materials. However, accurate measurements of the amount of weathering in terms of areas and volumes have not often been performed due to the limitation in the measurement method for detailed, three-dimensional surface morphology. Here we demonstrate terrestrial laser scanning to describe three-dimensional surficial morphology of a weathered material: sandstone blocks used for masonry piers of bridge on a shore platform at Aoshima, Miyazaki in western Japan. The blocks have suffered from salt weathering above the sea level since the construction of the bridge in 1951. Weathering-induced depressions of sandstone blocks well develop in the spray zone. Our approach revealed sub-centimeter scale morphology of the block surfaces, as well as weathering depths and volumes of each block. Spatial distribution of the amount of weathering was also examined with regard to the sea level and the rock surface hardness. Continuous measurement of such detailed morphology will be necessary to clarify the contemporary rates of weathering therein.

Keywords: Weathering, Sandstone, TLS, Rock strength