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

MUKOYAMA, Sakae[1*] ; HOMMA, Shin'ichi[1]

[1]Kokusai Kogyo Co., Ltd.

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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