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Development of new method for measurement of surface deformation, using multi-temporal digital geomorphic image analysis

Sakae Mukoyama[1*], Masayuki Sakagami[2]

[1]Kokusai Kogyo Co., Ltd., [2]Kokusai Kogyo Co., Ltd.

It is not easy to measure the small-scale ground deformation efficiently in the large area caused by the earthquake or the landslide. In this study, the new method to measure a small-scale displacement of the ground quantitatively and easily by image analysis using the geomorphic image made from DEM was developed.
When displacement is generated in an arbitrary direction on the undulating ground surface, the difference of elevation on the same coordinate point of DEM includes values which originated from vertical movement and also from horizontal movement of the slope. The value of difference of elevation is easily calculated from bi-temporal DEMs. However, it is necessary to obtain the movement locus of three dimensions of the same point in order to understand the distance and direction of the ground movement correctly. Because DEM doesn't have attributes other than the elevation value in the grid, the same point cannot be tracked by distinguishing the kind of the feature in surface of the ground like the aero-photo measurement. Therefore, the movement of ground cannot be tracked only by the difference of the coordinate value of three dimensions of an individual grid point. However, if a suitable relation of multiple grid points that are not a uniform character in an arbitrary small area can be known as a parameter for characteristic feature of the surface, the movement is able to be extracted by tracking such a feature.
In this study, the method of extracting the vector of ground displacement was developed by applying the technique of the image matching analysis to the visual image of the geomorphic quantity. Because the image is two-dimensional planar surface, and the distance that can be measured directly is a horizontal element, elevation value corresponding to each planar coordinate point is necessary to calculate the three-dimensional vector. However, because the image made from DEM has the elevation value in all grid points, the vertical component is available from the elevation values of both endpoints of the vector calculated on the image. A remarkable advantage of this technique is neither mapping for the measurement nor selection of specific characteristic for tracking is necessary. And, the movement quantity is calculated from a lot of point at random. High resolution DEM that can be made by the airborne laser survey etc. is useful as a terrain model to make the measurable image. It is necessary to correct the measured data if there is wide area crustal movement caused by the earthquake etc. For a good image matching analysis, it is preferable that the image should show geomorphic characteristics accurately, and displacement should be calculated from geomorphic quantity without the azimuthal anisotropy. The PIV method was used for the image matching analysis in this study, though there were various existing methods. The movement is identified by the image correlation, and the movement vectors were calculated after several movement parts in the search area had been extracted, and averaged in each area. In the image matching analysis, the displacement of about 1/10 size of a pixel is usually calculated by sub-pixel interpolation. In this study, though DEM in 2m grid was used, the amount of displacement that can be extracted is thought to be about 50cm, considering error of about 30 cm in the laser measurement.
As a case study, this technique was applied to the measurement of the ground deformation at the Iwate-Miyagi Nairiku earthquake (2008). The slope map made from 2mDEM before and after the

earthquake was used for image matching. As a result, the small movement of a large-scale mass movement was able to be estimated. Additionally, the movement direction of ground surface was calculated correctively by adding the reference point data of wide area crustal deformation. This method is effective for the measurement of the creeping landslide or the tracking of transitional deformation of volcanic body etc.

Keywords: Digital Elevation Model, airborne laser scanner, image analysis, mass-movement