Effective window size in topographic measurement for the assessment of shallow landslides

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Recently, the resolution of available DEM is increasing from dozens of meters to several meters with the spread of LiDAR. But a very detailed DEM, such as 1 or 2 m spatial resolution is too much detailed for the assessment of shallow landslides, because most of shallow landslides are dozens of meters in diameter and the default setting for topographic measurements has been 3 by 3 matrix of neighboring elevations. The matrix (window size) should be larger to deal with the problem.

In this presentation, we introduce a case study that investigates the optimum window size for the assessment of shallow landslides using 2 m DEM of LiDAR in a 20 km^2 mountains of Tertiary sedimentary rocks between Izumozaki and Nagaoka in Niigata Prefecture. The study area lies at altitudes between 45 and 345 meters. According to 1:50,000 geological maps by GSJ, the study area is composed of Miocene to Pleistocene interbedded sandstone and mudstone, massive mudstone, siltstone, and sandstone. The study area was damaged by heavy rainfalls such as the August 1962 heavy rainfalls and the July 2004 heavy rainfalls. Most of shallow landslides were less than 30 m^2 and occurred in steep valleys.

We investigated the optimum window size as follows. We first calculated slope gradients and values of the Laplacian by various window sizes. Then discriminant analyses were done using raster data of shallow landslides as an objective variable, raster data of slope gradients and values of the Laplacian as explaining variables. A window size which showed highest score in the discriminant analysis was the optimum window size. We also did discriminant analysis using various grid spacing DEM at 3 by 3 window size. Easy terrain classification maps were produced for the verification.

Here are methods to calculate slope gradients and values of the Laplacian. Slope gradient is calculated as follows. The appropriate surface is produced by the first equation:

Z = ax + by + c

Three parameters solved by the least square method are:

a = IH/k(n), b = JH/k(n), c = $H/(2n+1)^2$

where (2n+1) is the kernel size and

k(n)= $\{ n(n+1)(2n+1)^2\}/3$

IH and JH are submatrix of the first derivatives along the X and Y axes. Slope gradient is:

S(degree) =180/PI∗Atan(sqrt(IH^2+JH^2)/k(n)D)

where D (m) is the grid size of DEM.

The filtering is a local multiplicative summation and easy to accomplish by computer program. Existing GIS software and sophisticated image processing software have ways of image operation and processing by user-designed filter kernel.

Lidges and valleys can be distinguished by a simple method using a LoG (Laplacian of Gaussian) filter (Iwahashi and Pike, 2007). LoG filter returns the plus value for a convex slope and the minus value for a concave slope. LoG filter is the second derivative of a Gaussian filtered image (Marr and Hildreth, 1980). The basic numerical expression of LoG filter is as follows:

$G(x,y) = -\{(x^2+y^2-2sigma^2)/(2PI*sigma^6)\}exp\{-(x^2+y^2)/2sigma^2\}$

Range of a kernel ends at the zero crossing. Larger value of sigma makes larger kernel.

References

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Marr, D., Hildreth, E.(1980) Theory of edge detection. Proc. R. Soc. Lond. B 207, 187-217.