AUTOMATIC IMAGE CLASSIFICATION OF LANDSLIDES IMPROVED WITH TERRAIN ROUGHNESS INDICES IN VARIOUS KERNEL SIZES

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1. INTRODUCTION

Image classification techniques are usually employed for landslide recognition whereas classification results are usually erroneous with both commission and omission error solely on basis of 2D spectral information of remotely-sensed images. Landslides are usually confused with houses, roads, and other bare lands because these ground features have similar spectral patterns. In this study, 3D airborne LiDAR data are integrated with SPOT images for improving landslide classification. Terrain roughness can be measured by DEM variations. The relationships between terrain roughness and occurrence of landslide can be formulated by numerical analyses of topography data. For example, the rougher topography inside the landslide is distinct from the smoother unfailed portions of the landscape [1]. The problem of spatially and temporally dependent geomorphological mapping of landslides has been challenged by the lack of high-resolution topographic data [2]. In this study, airborne LiDAR data of 1m grid are used to explore the possibility of improving landslide classification. Data layers derived from LiDAR DEM include slope and terrain roughness indices such as diversity, dominance and relative richness. Different kernel sizes are tested to examine their effectiveness in improving classification accuracy.

2. STUDY AREA AND MATERIALS

The study area is located in southeast part of Taoyuan County of northern in a sub-basin of Shimen Reservoir. The high frequency of landslides in study area is due to its geological settings with thick overburdens of weathered geological formations of alternation of sandstone and shale. The materials used in this study include ortho-rectified aerial photos, SPOT images and Airborne LiDAR DEM. The resolution of ortho-photos is 0.5 meters, which is used for establishing ground truth of landslides. SPOT 5 images is at a resolution of 2.5 meters in super-mode. LiDAR DEM derived from point cloud is resampled to 2.5 meters. Both the SPOT images and LiDAR survey are conducted after Typhoon Longwang in November of 2005.

3. SURFACE ROUGHNESS INDICES DERIVED FROM AIRBORNE LIDAR DATA

LiDAR DEM is the first derivative product from LiDAR discrete points. Subsequently, slope and indices of surface diversity, surface dominance and surface relative richness can be derived from DEM. These indices are employed to and incorporated with SPOT images for distinguishing landslides from others.

The slope gradient algorithm used in this study is the third-order finite difference weighted by reciprocal of squared distance algorithm. It uses the eight neighboring elevation values bordering the central elevation cell and uses eight grid points to calculate each slope value. These weightings are proportional to the reciprocal of the square of the distance from the kernel center [3].

The Diversity Index [4] is calculated over the local neighborhood of each pixel, defined as a 3x3 neighborhoods. The formula is as follows:

$$H = -\sum_{K=l}^{S}(P)\times\ln(P)$$

Where p is the proportion of each class within the neighborhood, ln is the natural logarithm[89] and n is the number of classes. The result is an index that ranges from 0-1 where 0 indicates a case where the surface is uniform within the neighborhood and 1 indicates maximum diversity possible of surface within the neighborhood.

The Surface Dominance Index [4] is calculated over the local neighborhood of each pixel, defined as a 3x3 neighborhoods. The formula is as follows:

$$\mathbf{D} = \mathbf{H}_{max} + \sum^{S}(\mathrm{PI.})\ln(\mathrm{Pk})$$

Where s is number of cell observed, P_K is the proportion of the elevation in cell k, H_{max} is the maximum diversity when elevation occur in equal proportions

Surface relative richness index [4] is another measure of diversity of surface, measured as:

$$\mathbf{R} = \frac{n}{n_{max}}\times 100$$

Where n is the number of different classes present in the neighborhood and n_{max} is maximum number of classes possible.

Surface diversity, surface dominance and surface relative richness indices are processed with 3x3, 5x5 and 7x7 kernel sizes to evaluate the influence with kernel size.

4. CLASSICIFICATION ALGORITHMS FOR ASSESSING THE EFFECTIVENESS

The classification was performed with the LiDAR derived data, including DEM slope, diversity, dominance and relative richness. These indices are integrated with SPOT 4 bands separately and performed with classification algorithms include Maximum Likelihood, Mahalanobis Distance and Minimum Distance. Finally, accuracy assessment was performed to compare classification results.

5. CLASSIFICATION RESULTS WITH VARIOUS KERNEL SIZE

The results of the landslides classification are obtained from the three classification algorithms and different data-sets using various combinations of LiDAR derivatives. Geomorphological indices are derived by the topographic information in a defined kernel size. The variation of the kernel size will certainly affect the contract of different type of terrains. Thus, Diversity, dominance and relative richness are processed with three kernel size. Results of improvement of classification accuracy as compared to those using only SPOT images are shown in table 1. (PA denotes Producer's Accuracy and UA denotes User's Accuracy).

Table 1 Accuracy improvement with different kernel size of LiDAR-derived indices

	Maximum Likelihood		Mahalanobis Distance		Minimum Distance	
	PA%	UA%	PA%	UA%	PA%	UA%
SPOT(4 bands only)	0	0	0	0	0	0
DEM Slope	+22.13	+27.78	+7.35	-0.8	+7.19	+4.75
Diversity_3x3	+21.25	**+11.64**	+13.22	**+1.94**	+0.01	0
Diversity_5x5	+25.69	**+12.38**	+17.09	**+1.26**	+0.02	+0.01
Diversity_7x7	+27.37	**+11.69**	+18.42	**+1.04**	+0.02	+0.01
Dominance_3x3	+3.76	+1.76	+0.99	+1.53	+5.97	+1.98
Dominance_5x5	+5.37	+3.53	+4.62	+1.89	0	0
Dominance_7x7	+8.47	+4.71	+6.52	+1.92	0	0
Relative Richness _3x3	+20.1	**+8.6**	+9.99	**-4.26**	0	0
Relative Richness _5x5	+25.78	**+4.26**	+14.79	**-8.48**	0	0
Relative Richness _7x7	+27.82	**−0.29**	+16.52	**-9.88**	0	0

6. RESULTS AND CONCLUSIONS

In this study, LiDAR DEM slope, diversity, dominance and relative richness are combined with SPOT 4 band images for image classification with algorithms including Maximum Likelihood, Mahalanobis Distance and Minimum Distance algorithms. The best result is obtained by Maximum Likelihood classification. As shown in table 1. The improvement of accuracy when including DEM slope is 22% in producer's accuracy and 27% in user's accuracy. The improvement of accuracy when including Diversity is 27% of producer's accuracy and 11% of user's accuracy. And, those for relative richness are 27% and 8%, respectively. There is no improvement at all with Minimum Distance algorithm when including indices of dominance and relative richness. Obviously, the algorithm is not sensitive to the data sets. Other classifiers can be further explored.

7. REFERENCES

[1]. J. McKean, J. Roering　J. McKean and J. Roering, Objective landslide detection and surface morphology mapping using high-resolution airborne laser altimetry, *Geomorphology* Vol.57, pp. 331–351, 2004.

[2]. Glenn, N.F., Streutker, D.R., Chadwick, D.J., Tackray, G.D.,Dorsch, S.J., " Analysis of LiDAR-derived Topographic Information for characterizing and differentiating landslide morphology and activity," *Geomorphology*, Vol.73, pp.131-148, 2006.

[3]. Jones, K.H. "Comparison of Two Approaches to Ranking Algorithms Used to Compute Hill Slopes," *GeoInformatica*, Vol.2, pp.235-256, 1998.

[4]. Jones, K.H. "Landscape ecology: The Effect of pattern on process," *Annual Review of Ecology and Systematics*, Vol.20, pp.171-197, 1989.