

LANDSLIDE DETECTION BY INDICES OF LIDAR POINT-CLOUD DENSITY

*Jin-King Liu^{*1}, Wei-Chen Hsu^{*2}, Mon-Shieh Yang^{*3}, Yu-Chung Shieh^{*4}, Tian-Yuan Shih^{*5}*

*1. NCTU and ITRI. #195, Chunghsing Road Sec. 4, Hsinchu County 31040, Taiwan. jkliu@itri.org.tw

*2. Industrial Technology Research Institute (ITRI), Hsinchu County 31040, Taiwan. ianhsu@itri.org.tw

*3. National Cheng Kung University (NCKU), Tainan City 70101, Taiwan. bermudagras@msn.com

*4. Central Geological Survey (CGS), MOEA, Taipei County 23568, Taiwan. hsiehye@moeacgs.gov.tw

*5. National Chiao-Tung University (NCTU), Hsinchu City 30010, Taiwan. tyshih@mail.nctu.edu.tw

1. INTRODUCTION

Airborne LiDAR mapping technology is capable of collecting a large volume and high density of discrete points with a height accuracy within 0.15m and horizontal accuracies within 1/1000th of the flight height. Basic products of airborne LiDAR include all points, ground points, digital elevation model (DEM), and digital surface model (DSM). The former two are vectors of discrete points and the later two are interpolated raster grids of the discrete points of the former two. The DEM and DSM grids are commonly used for subsequent applications whereas point clouds are rarely used for subsequent analysis. LiDAR discrete points are worthy of a further study due to the fruitful information adhered with the attributes of individual points. Point density has been used as an important indicator of DEM/DSM quality [1][2][3][4]. An understanding of the forest closure and crown density can be obtained by inspection of the point-density distribution of point clouds [5][6][7]. Therefore, point density derived from specific properties of point clouds can be used to explore the possibility of extracting landslide information from point clouds. Landslides are common threatens in Taiwan because the physiographical environments of heavy rainfalls and active tectonic movements. Visual interpretation of shaded-relief image derived from DEM is usually adopted by geologists. In this paper, possible derived indices from point clouds are discussed first and then experiments of selected indices are made to find out the most descriptive ones for landslide detection.

2. EXPERIMENT SITE AND LIDAR DATA

The study area is located in I-Lan County of northeastern Taiwan where is on the track of the Typhoon Kalmaegi attacked Taiwan on July 16th~18th, 2008, about nine month after Typhoon Krosa on October 4th, 2007 in this area. The dataset for the experiment was taken on 4th November, 2008 after Typhoon Kalmaegi. In general, the accuracy of bare grounds checked in the field is about 0.15m. An area covering 2 km by 2 km is selected for the experiment. The overall point density of the study area is 2.75 points/m² with ground point density of 0.75 points/m², as shown in TABLE 1.

TABLE 1 SOME STATISTICS OF THE LIDAR DATA USED IN THIS STUDY

Type of points	All points	Ground points	Only-echoes points	Multiple-echoes points
Total number of points	12,142,434	3,320,615	5,789,148	6,353,286
Average point density (pts/m ²)	2.75	0.75	1.31	1.44
Minimum height (m)	574.08	574.08	574.08	577.72
Maximum height (m)	1290.43	1279.65	1290.43	1290.29

3. DERIVATION OF POINT DENSITY INDICES

The attributes of individual points of LiDAR point clouds are recorded in a LAS format. The format contains binary data consisting of a header block, variable length records, and point data [8]. Each point data record includes the XYZ coordinates, intensity, return number, number of returns, scan direction, and classification of the point. The coordinates, return number, number of returns, scan direction, and classification are closely related to the geometry of laser scanning configuration and thus relevant to the point density of unit ground area. The spatial distribution of point density implies the properties of the land surface. For discriminating landslide and non-landslide lands, the types of point clouds for point density enumeration can be categorized as follows: (1) all points, (2) ground points, (3) single-echoes points or only-echoes points, (4) multiple-echoes points, i.e. (first + intermediate + last) returns, (5) first-return points, (6) intermediate-return points, and (7) last-return points. Secondary indices can also be created by combining two or more types of point clouds, for example, penetration rate can be derived by the ratio of ground and all points denoting the rate of points hitting the bare ground. For exploring the capability of point clouds for the detection of landslides, four types of point density with five searching radii are used including point density type of all points, ground points, only-echoes points, and multiple-echoes points. Comparison of them will be made to search for most descriptive ones for landslides.

4. METHODS OF POINT DENSITY CALCULATION

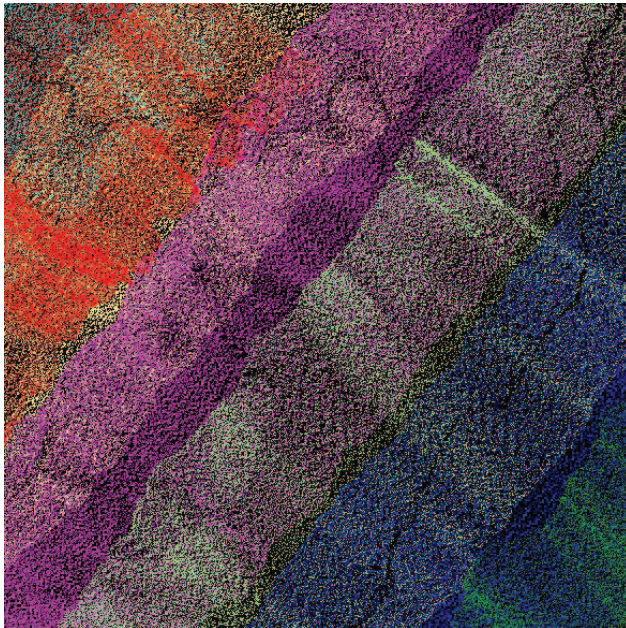
Point density can be measured by various approaches [1]. In this study, point density is measured by subdividing the surveyed area into grid cells, then computing the unit density of the number of points in a circle with certain searching radius centered at the cell center. A software application is implemented in this study to cater for the output grid size, searching radius, and type of points. This method is comparable to that by Crosby [9], whereas the function of reading PTC file of Terrascan for point class definition is also implemented. Point density distribution of ground points is affected by the criteria and procedures of both automated and manual editing process. Nevertheless, point density except that of ground points is mainly decided by operation factors include pulse rate, look angle, flight height, aircraft attitude, flight speed, strip overlap, terrain relief, and above-ground objects. Because average ground points is 0.75 pts/m², 1 m is selected for grid spacing. To

cater for uniformity of point distribution and ground surface undulation, five searching radii are used, i.e. 0.707, 1.414, 3, 5, and 10 m.

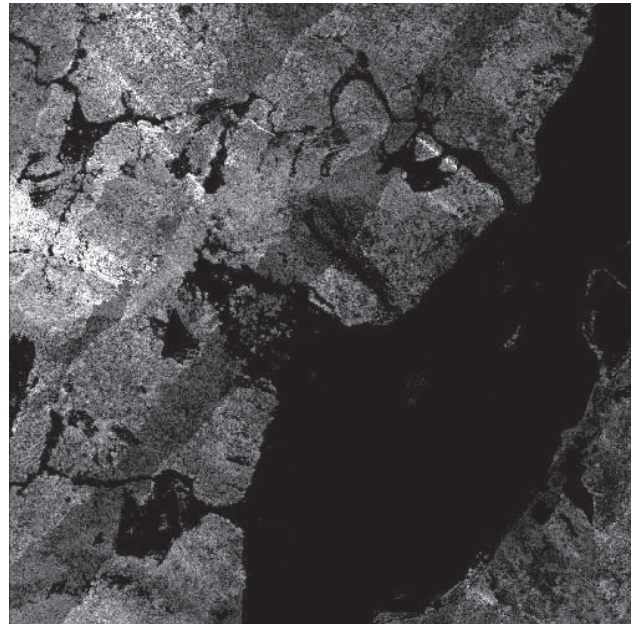
5. RESULTS AND DISCUSSIONS

After examination of the test results of the four types of points versus five searching radii, findings are as follows:

- (1) Striping noise of point density map is obviously affected by flight speed and strip source as shown in Fig. 1.
- (2) Point density map of multiple-echoes point gives better contrast between landslide and non-landslide areas than any maps derived from other three types of point density, as shown in Fig. 1(B).
- (3) Point density map with a searching radius of 1.414m shows best result among all radii for 1m grid spacing. A larger radius can not give better enhancement of landslides.
- (4) Although the overall point density of only-echoes points of the whole study area is similar to that of multiple-echoes points as shown in TABLE 1, a conspicuous contrast of landslide area is observed on the density map of multiple-echoes points other than that of only-echoes points. This is due to a high concentration of multiple-echoes points in forested land and most of bare grounds are covered by only-echoes points.
- (5) Landslide feature is conspicuous in some part of the density map of ground points whereas it is vague in other parts. This is a consequence of the factors of penetration rate in different part of the area and the filtering process of non-ground points with both automated algorithm and manual editing. However, on the map of all points overlaid by ground points, landslides features can be enhanced for visualization. Nevertheless, commission errors are serious on this map, especially in those bare lands which are not landslides. These errors might be eliminated by slope gradient of ground surface in a later step.



(A) Flight strip source ID



(B) Density map of multiple-return echoes with $r=1.414\text{m}$ and grid spacing = 1m

Figure 1 Results derived from airborne LiDAR data of the study area.

6. CONCLUDING REMARKS

Point density maps derived from various types of LiDAR point clouds are tested and examined in this study for understanding the possibility of obtaining useful thematic maps from discrete points for landslide detection. Results show that some indices of LiDAR point-cloud density exhibit good contrast between landslide and non-landslide areas and, thus, they can be used for deriving useful thematic maps. Four types of points are selected in this study with output grid spacing of 1m and searching radii of 0.707m, 1.414m, 3m, 5m, and 10m. Density map of multiple-echoes points with searching radius of 1.414m gives the best result. All density maps except that derived from ground points are prone to striping noises due to flight speed and strip source. This has to be eliminated in a later study to explore the best capability of point density maps.

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