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Detection of tropical landslides using airborne lidar data and multi imagery: A case study in genting highland, pahang

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Abstract. The landslide geomorphological system in a tropical region is complex, and its understanding often depends on the completeness and correctness of landslide inventorization. In mountainous regions, landslides pose a significant impact and are known as an important geomorphic process in shaping major landscape in the tropics. A modern remote sensing based approach has revolutionized the landslide investigation in a forested terrain. Optical satellite imagery, aerial photographs and synthetic aperture radar images are less effective to create reliable tropical DTMs for landslide recognition, and even so in the forested equatorial regions. Airborne laser scanning (ALS) data have been used to construct the digital terrain model (DTM) under dense vegetation, but its reliability for landslide recognition in the tropics remains surprisingly unknown. The present study aims at providing better insight into the use of airborne laser scanning (ALS) data. For the bare-earth extraction, several prominent filtering algorithms and surface interpolation methods, i.e. progressive TIN densitification, morphological, and command prompt from Lastool are evaluated in a qualitative analysis, aiming at removing non-ground points while preserving important landslide features. As a result, a large landslide can be detected using OOA. Small landslides remain unrecognized. Three out of five landslides can be detected, with a 60 percent overall accuracy.

1. Introduction

Landslide is a natural disaster which causes significant damage to properties, environment and lives. According to the International Association for Engineering Geology and the Environment (IAEG) landslide ranks third amongst disasters in the world. Landslides usually happen when the structure of the landform is disturbed by human activity. For instance, cutting-off the slope without following the specification developed by National Slope Plan. In addition to a high precipitation rate in tropical regions and disappearance of tree roots to stabilize the slope, the area is prone to landslide (Rienstenberg, and Dunford, 1984). This scenario usually happens especially in developing country where the country does not have enough open area for housing (Pradhan et al., 2012). Aerial photo image and satellite images are able to do quantitative changes in slope morphology and to determine of movement vectors of properties of landslide. However, an image interpretation from aerial photo for detection of landslide area is less effective since the landslide is invisible to image when it

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covered by dense canopy (Pradhan et al., 2012). LiDAR data is represented by points cloud and it has the advantage to penetrate through vegetation. In addition, the accuracy of LiDAR is quite accurate in sub meter level. Since the detection of landslide in tropical region faces difficulties such as unable to penetrate through vegetation, the advanced technology through laser approach was introduced. LiDAR can penetrate through canopy depending on the repetition rate of the sensor. The ability to penetrate through vegetation is significant to detect and map the landslide under forested area (Haugerud et al., 2003; Schulz, 2007; Eeckhaut et al., 2007; Booth et al., 2009; Razak et al., 2009) compared to aerial photograph and optical remote sensing. The aim of this study is to detect landslide in Genting Highland area by using airborne laser scanning. This broad objective is supported by the following objectives:

1. To investigate qualitatively the performance of different LiDAR filtering approaches in removing non-ground points clouds.

2. To generate different parameter layers i.e DTM, hillshade, openness, roughness, plan curvature, flow accumulation, flow direction, slope aspect, slope gradient, red, blue and green from aerial photo over landslide area by using different interpolation methods.

3. To delineate the landslide area using DTMs generated using object-oriented.

2. Study area

Genting Highlands is located at 3°25’45”N and 101°30’24”E in Bentong District. It is only 50 km from Kuala Lumpur, the capital city of Malaysia. It lies within the Titiwangsa Range (main range) and is on the Pahang and Selangor border. The summit region of Genting Highlands together comprises of Gunung Ulu Kali, Gunung Chin Chin, Gunung Mengkuang and Gunung Lari Tembakau also Gunung Purun. The hill now is totally replaced by hotels and amusement park complexes, is one of the most disturbed cloud forests in Malaysia. Gunung Ulu Kali which is approximately 1770 m above sea level is the highest peak of the summit region. Metrological data provided by The Resorts World Sdn. Bhd. shows that mean monthly air temperature was 26 -28°C with a mean annual rainfall of 3534 mm and mean relative humidity of 53.7 percent. The average degree of the slope over the area is 45- 60 degree with slope height 15 metre. The study area is restricted area for outsider, only construction workers can access the area. Tropical forest is cover within area of study and the terrain is rugged. The lithology of within the area consists of acid intrusive and vein quartz of rock. The area of study is approximately 3 km^2.

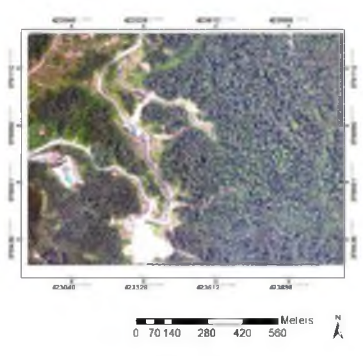

Figure 2.1: Study area

3. Methodology

The LiDAR data which consists of both ground and non-ground points were acquired from an Optech ALTM 3100 system with 25 kHz of repetition frequency. They were observed between 1100 meter of flying height and with 45 degree of scan angle. The original airborne

LiDAR data has already corrected the position (*X Y Z*) using Real Time Kinematik (RTK) system. In order to remove the non-ground points progressive TIN densification algorithm is applied. After the non grounds points are removed, DTM is generated. Later it produced the derivatives of DTM in hydrological and geomorphologic parts before delineating the landslide using object-oriented classification.

Cell size	3
Window base	2
Power increment	1
Maximum window length	8
Z factor	86
Initial radius	1
Initial threshold	0.6
Maximum threshold	9999
Data mode	Terrain
Rotation angle	0
Rotation times	0
Filter direction	X and Y

Figure 3.2. Progressive TIN densification parameters.

4. Result

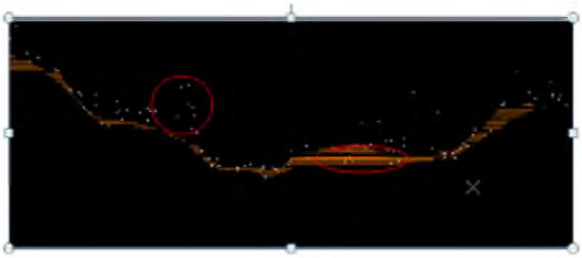

Figure 4.1: Morphological filter result.

Figure 4.2: by command-prompt lasground.

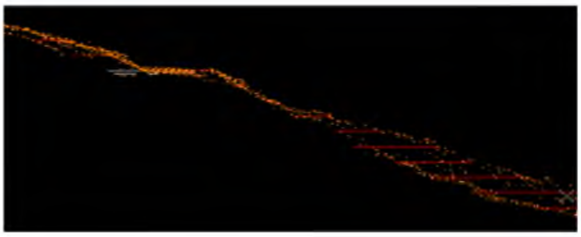

Figure 4.3: From Progressive TIN densification filter.

From the figure 4.1, shows that the non ground is not filtered well in the circle area. The orange line is represents the contour line whereas the white points cloud is represent the ground points. The points cloud is belong to non-ground points because the points is not located in the contour line. In the oval shape it shows that the ground points are in contour line. Even some of the ground points are filtered well but most of the vegetation is not filtered out. From the figure 4.2 it shows that all the vegetation points are filtered out, but the building is belong to ground point. The circle one is a tank. Even the non ground points are filtered well but the building points are not filtered out, and the building is assign to ground points. By using the progressive TIN densification, the ground points are quite well filtered. All the ground points in brown colour are on the contour line. Table 4.1 summarizes the qualitative comparisons of filter.

Table 4.1: Qualitative comparison of filter.

Participant	Morph filter	Lasground filter	Progressive TIN
Detached object			
Building on slope	#	#	R
Vegetation			
Vegetation	#	##	###
Vegetation on slope	#	##	###
Low vegetation	#	#	##

– good R - removed

– fair # - poor

	Morphological	Progressive TIN	Lastool
Good		Good almost non ground is removed	
Fair			Fair remove vegetation but building still exists.
Poor	Worst not remove type I error.		

In order to select the appropriate scale for multi-resolution segmentation, the scale factor, shape and compactness parameter are determined first. With the help of aerial photo image, it is better for visualization of landslide area.

With the scale 45, shape 0.6 and compactness 0.5 small landslides can be recognized, but for the large area of landslide there are still more segment upon it. According to the research in Italy for detection of landslide by using OOA classification using the single pulse of LiDAR carried out by Van Den Eeckhaut et al (2012), she used the variation of scale factor between 5 and 50. By the scale 45, two small slides can be identified correctly. However, for the large slide, this 45 scale factor in multi-resolution segmentation algorithm, the large slide in this area is segmented in two or three segments.

For the scale of 45, with the shape 0.4 and the compactness 0.5, the crown and the main scarp of landslide can be seen from the image. There are only two levels classifications in this study. Level 1 shows the small slide can be identified using the scale 45; with compactness and shape value are 0.5 and 0.4. Level 2 with the modification of scale and using the object based classification, the large slide can be found. Even though there is one large slide separate in two parts, using the knowledge of landslide during site visit, the multi-resolution merging is used to merge one small segment to landslide class. It is the challenge in OBIA, the prior knowledge of the object is really crucial (Martha, 2007). Researchers, who have no knowledge about landslide, must coorporate with a landslide expert person.

Figure 4.4: Accuracy assessment by merging the automatic classification layer with the manually classify.

Table 4.2: Landslide type

Landslide name	Object features	Landslide type
Landslide 1	Asymmetry : 0.91	Debris flow
	Mean slope : 31.16 degree	
	Mean curvature: -	
Landslide 2	Asymmetry:0.8	Debris slide
	Mean slope:33.21 degree	
	Mean curvature: -	
Landslide 3	Asymmetry:0.67	Rotational slide
	Mean slope: > 45 degree	
	Mean curvature: < -1	

Overall all of the landslide area found underestimated (Table 4.4). Landslide 3 shows the highest value of underestimation (51%) mainly due to the size of landslides and density coverage of the vegetation. This study demonstrates that the filtering process can still be improved in order to get higher accuracy for identifying forested landslides. As expected, the accuracy of landslide detection in open area was good with only 5.3 percent of misclassified and total of 7.4 percent underestimated. But for the small landslide the different parameter of scale, compactness and shape are recommended. Total number of detected landslide manually was five, whereas only three out of five landslides were retrieved when the automatic approach was implied. The overall accuracy was reported 60 percent correctly detected.

Martha (2011) identified the landslide from the object features based on the following attributes presented in Table 4.6. Landslide 1 was identified as a debris slide because the asymmetry value was less than 0.95. Moreover, the field investigation indicates the water flow nearby the area coming from above hill. Landslide 2 is debris slide. The asymmetry value of both landslides is different in a small value only 0.1, but in prior knowledge of landslide, it called the debris slide because there is no water flow. It is supported by the site visit where the distance of landslide is 10 meter from the water tank. The study suggested that landslide 3 is considered as a rotational slide, with clear indication of negative mean curvature value illustrating the concave surface. The rupture of the landslide is quite deep, with the mean of the slope was found more than 45 degree.

5. Conclusions

This study presents the experimental assessment of LIDAR-derived derivatives products to automatically recognize and retrieve the tropical landslides beneath dense vegetation in the rugged mountainous region. Airborne LiDAR is a promising tool to detect landslide in different tropical regions with the additional information of derivatives of DTM.

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