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Identification of bicycle lane steepness from high resolution LIDAR data for Campus Geographical Information System

Ko Ko LWIN*, Zhou YIFEI* and Yuji MURAYAMA*

Abstract

Bicycle lanes are the most prominent travelling paths in many universities. Measurement of safety factors for these bicycle lanes is essential for university authorities in order to concern public safety and to implement an effective campus facility management tasks. Information of bicycle lane steepness is useful for daily bicycle lane users through Campus Web-GIS System, in order to prevent unnecessary accidents while they are riding, especially in the night. In this study, we used very fine scale Light Detection And Ranging (LIDAR) data to identify the bicycle lane steepness by integration with field investigation and deliver the information through Campus Web-GIS System. Based on our study, LIDAR data are much promising to detect bicycle lane steepness factor in open spaces. However, the accuracy was reduced in some areas where the lanes are covered with trees and bridges. Insensitive field investigations are required to correct them. We built a Web-based real-time geospatial data collection system for data validation purposes by utilizing high-resolution aerial imagery and mobile communicational devices to collect, store, modify and update the results.

Key words: bicycle lane steepness, slope, LIDAR data, field data collection, Campus GIS

1. Introduction

Although LIDAR techniques have been available since the 1960s, they have only become commonly used in the past few years due to the lack of computational resources and sophisticated software to handle massive points cloud data (Lwin and Murayama, 2009). LIDAR data can now provide very accurate height information for land surface features such as buildings and trees. Digital Volume Model (DVM) derived from LIDAR data are also increasingly being used for population estimation at the urban scale and are being integrated with very high resolution imagery with good results (Ramesh, 2009; Qiu et. al., 2010; Lwin and Murayama, 2011; Weng, 2012). Although LIDAR technology measures the height of the surface known as Digital Surface Model (DSM) very accurately, the measurement of object height known as Digital Height Model (DHM) is fully dependent on the accuracy of the Digital Terrain Model (DTM) or bare Earth since DHM was made by differencing between DSM and DTM (Fig. 1). Normally DTM was generated from LIDAR last returns which are hitting from the ground and estimate to other hard objects areas such as buildings, dense trees, bridges, etc., since LIDAR cannot penetrate these hard objects. The terms, DSM, DTM and DHM, are mostly suitable to use in high resolution LIDAR data since building heights, tree heights can be distinguished. The term Digital Elevation Model (DEM) is commonly suitable for coarse spatial resolution elevation data (i.e. 30m, 90m, 1Km), representing the height information as raster cells.

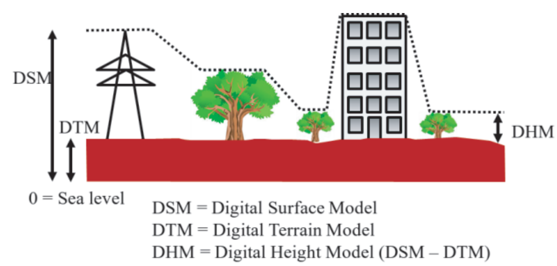

Fig. 1 Illustration of DSM, DTM and DHM in LIDAR data processing

In our previous study, we used LIDAR data to estimate the building population (Lwin and Murayama, 2011) and identification of housing types such as single multiple unit, family multiple unit and family single unit based on building size, shape and smoothness of the roof in Tsukuba City (Lwin and Murayama, 2012). Moreover, at the urban or intra-urban scales, further research is needed to establish the best methods and procedures for population estimation, taking advantage of the very high spatial resolution satellite imagery and LIDAR data that are now widely available (Patino and Duque, 2013). Under the LIDAR data processing, the high resolution aerial photo (orthoimage) is also important to identify the actual landscape information. In this paper, we generate slope from LIDAR derived DTM to identify the bicycle lane steepness and combine with field investigation.

2. Study area and methodology

2.1. Study area

Study area is University of Tsukuba campus which is located in Tsukuba City, Ibaraki Prefecture in Japan (Fig.

* Division of Spatial Information Science
Graduate School of Life and Environmental Sciences,
University of Tsukuba

2). The University has 28 college clusters and schools with a total of around 15,000 students. The main Tsukuba campus covers an area of 258 hectares (636 acres), making it the largest single campus in Japan.

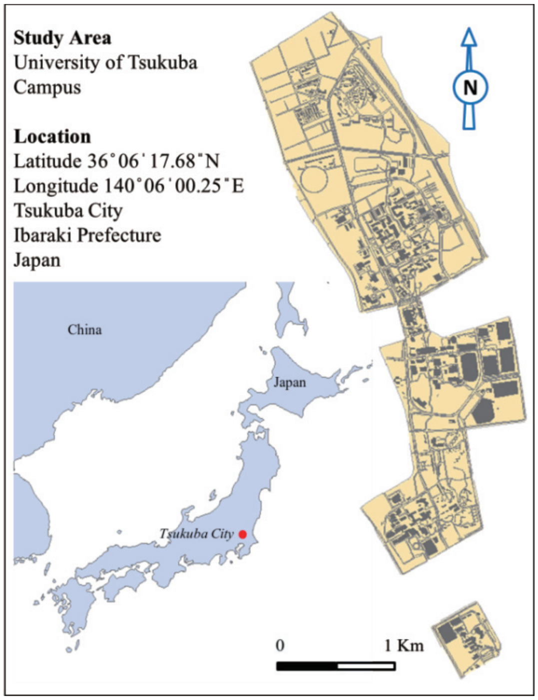

Fig. 2 Study area (University of Tsukuba Campus)

2.2. Data and sources

Table 1 shows the list of data and purpose to be used in this study.

2.3. Methodology

Fig. 3 shows the research flow of this study. We acquired original DTM from PASCO Corporation and collected some last return signals from DSM based on 8cm orthomage. Because we need more ground hitting signals for DTM generation. Orthoimage, 8cm spatial resolution helps us to identify actual land scape features such as trees, buildings, road surface, etc. (Fig. 4 A and B). After that, new DTM was generated at 50cm spatial resolution. This new DTM was used to calculate slope of the surface. We also digitized bicycle lanes based on 8cm orthoimage and segmented/ divided into 5m intervals. Later, this 5m segmented bicycle lanes were buffered by 2m each side of the lane and make polygons. Slope in degree was calculated for each polygon by applying zonal statistic as a table function between 50cm modified DTM and 2m buffered polygons (Fig. 5). Additional field investigations were made for data validation and modification of the results.

Table 1: List of data and purpose to be used

Data and Source	Description	Purpose
Digital Surface Model (DSM) (Source: PASCO Corp.)	Point feature in ESRI shape format Average point spacing is 0.9 m	To collect some ground hitting points
Digital Terrain Model (DTM) (Source: PASCO Corp.)	Point feature in ESRI shape format Each point is 5 m regular spacing	To compute slope
Orthoimage (Source: PASCO Corp.)	GeoTIFF format 8 cm X 8 cm spatial resolution RGB True Color (along with LiDAR surveying) A total of 45 scenes were used	Used as a base map and landscape visualization Selection of LIDAR return signals To digitize bicycle lanes on orthoimage
Digitized Bicycle Lanes	ESRI Shape format Onscreen digitizing based on 8cm orthoimage	To compute slope for each 5m bicycle lane within 2m buffered zone

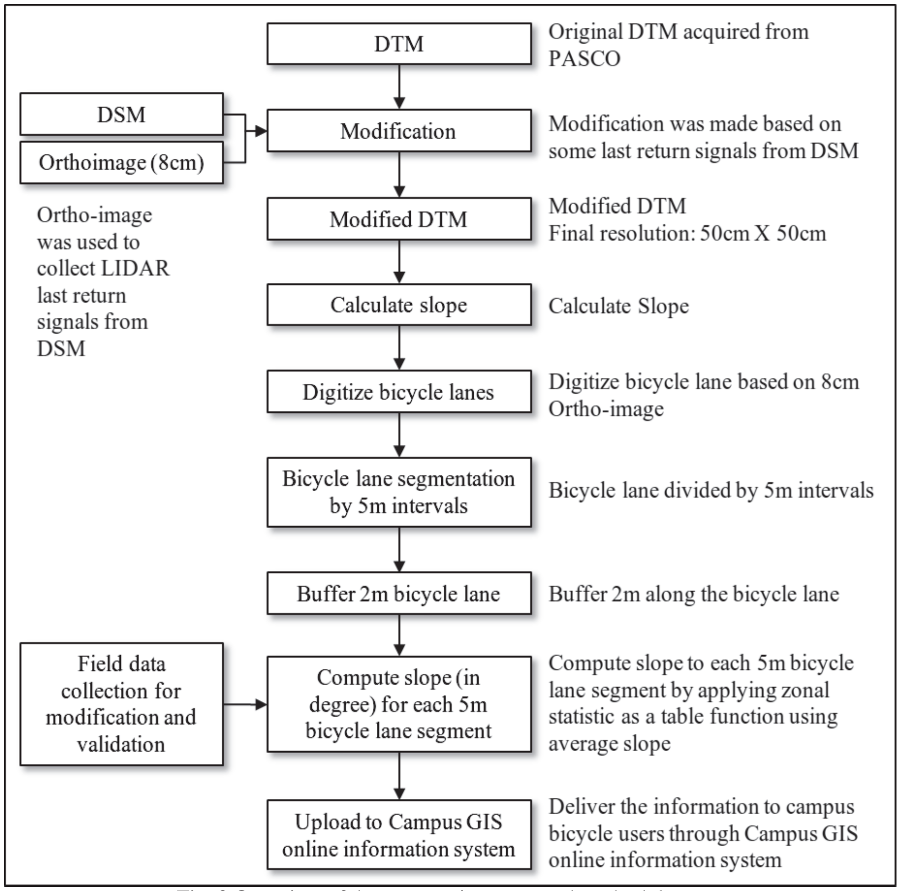

Fig. 3 Overview of data processing steps and methodology

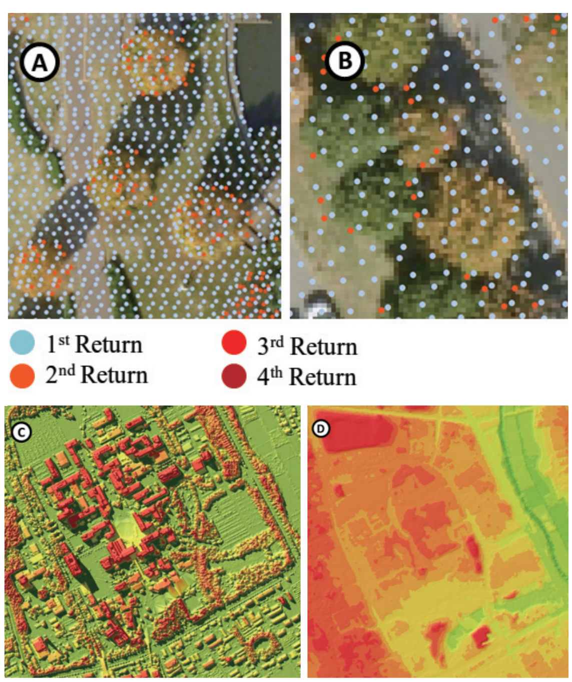

Fig. 4 Manual collection of ground hitting points from DSM to modify original DTM (A & B: 2nd, 3rd and 4th returns are more prominent in edge of the trees whose signals are returning from the ground, C: Shaded DSM, and D: Shaded DTM

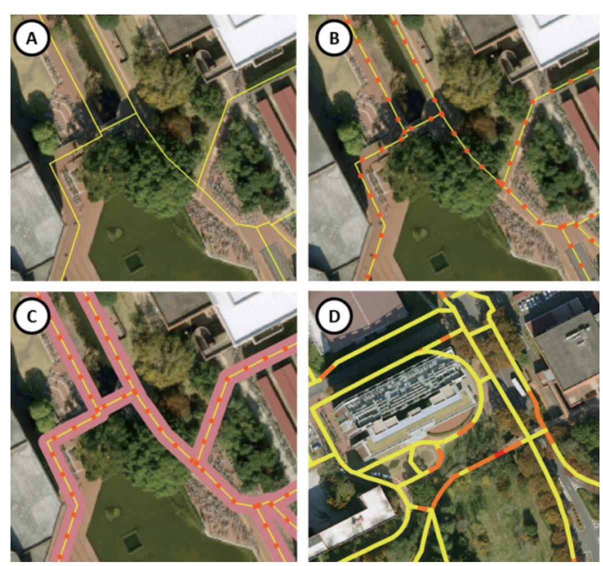

Fig. 5 Identification of bicycle lane slope process (A: Bicycle lane onscreen digitizing, B: Bicycle lane segmentation by 5m intervals, C: Buffer 2m each side of the bicycle lanes, and D: Calculate slope for each 2m buffered polygon by using zonal statistic as a table function in ArcGIS)

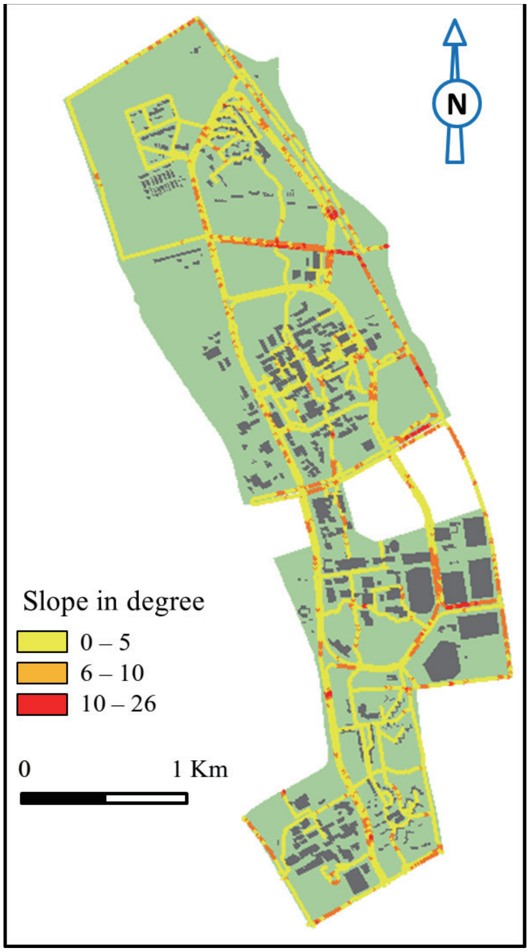

Fig. 6 Bicycle lane slope map for university campus

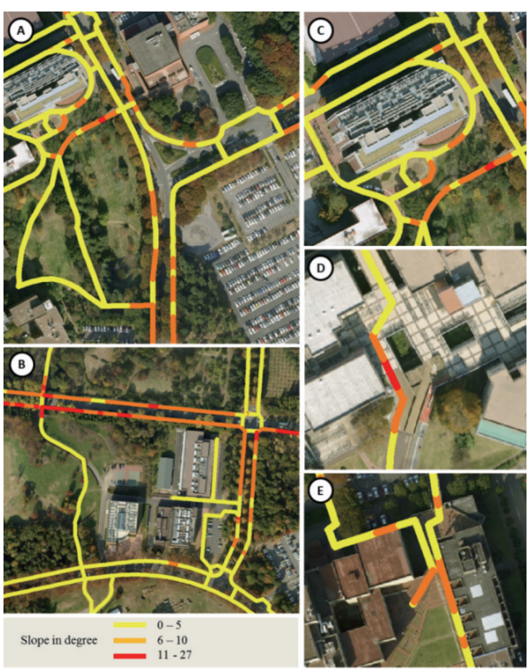

Fig. 7 Results in various landscapes (A: results in open space area, B: results in massive trees and bridges covered area, C, D and E: very promising results places)

3. Results and Discussion

Fig. 6 shows the slope in degree of bicycle lane inside the campus. We found out the results of open space areas are very satisfactory and even the slope of small hills (less than 10 degree) can be detected (Fig. 7 C, D and E, much of the steepness lanes inside the campus can be spotted by LIDAR data). However, the results of some parts were incorrectly identified due to lanes covered by massive trees and bridges (Fig. 7 B). Additional field investigations were carried out for those areas to correct them.

4. Mobile field data collection and validation of the results

We also conducted the field survey with smart phone. We used iPhone slope measurement program to measure and collect the various places inside the campus and validated the result (Fig. 8). According to the results, average 1 to 1.5 degree varies between LIDAR result and field measurement.

The final validated data was uploaded into Campus GIS system to deliver the bicycle users inside the campus. The information can be reached at:

http://land.geo.tsukuba.ac.jp/campusgis

5. Conclusion

Identification of bicycle lane steepness from LIDAR data is very promising in open-spaces, however, less accuracy in trees and bridges covered areas. Additional field investigation is required to correct and modify them. The information of bicycle lane steepness is important for bicycle riders inside the university campus especially at night-time and the campus administrators to identify the safety factor for campus management purposes.

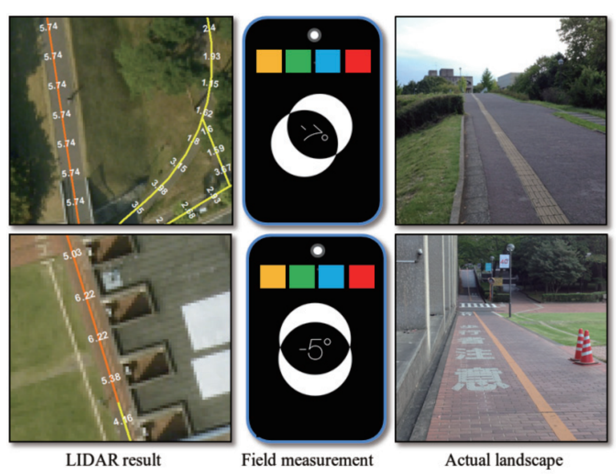

Fig. 8 Field data collection and validation of the results with smart phone

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