MODELLING FOREST CANOPY USING AIRBORNE LIDAR DATA

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ABSTRACT

The objective of this study was to model the canopy structure of a 25-hectare subtropical forest dynamics plot in northern Taiwan using airborne lidar data. This study utilized an airborne laser scanner (Leica ALS50) and a digital camera (Rollei AIC) to obtain 3D measurements about the forest dynamics plot. The lidar point clouds were classified into ground and surface points, then the canopy height model was derived by subtracting ground height model from surface height model. The data derived from lidar were compared to the data produced using photogrammetric approach and ground truth data. The results indicate that lidar data can effectively model the forest canopy.

1. INTRODUCTION

The Center for Tropical Forest Science (CTFS) program of the Smithsonian Tropical Research Institute (STRI) consists of a network of large-scale Forest Dynamics Plots (FDP) including 18 sites in 15 countries. The CTFS program is unique because each plot uses a standardized sampling methodology, which allows scientists to directly compare data collected at different sites. Using data from the network of field sites, the scientists can understand the forest diversity and change in Asia, Africa, and Latin America (CTFS, 2006). Among these FDPs, the Fu-shan Nature Reserve site, with an area of 25 hectares, is the largest site in subtropical area (Sun, 2006; Hsieh, 2006). The data collected at different sites form an invaluable database for forest related studies and regional forest management. Furthermore, the database provides ground truth data that are required for large-scale forest inventory using remote sensing data such as satellite imageries, aerial photographs, radar data, and LiDAR (**Li**ght **D**etection **A**nd **R**anging) data.

Airborne lidar technique has certain advantages over photogrammetric procedures, particularly the capability of lidar to obtain ground measurements in forested area provide accurate estimation of DTM (Baltsavias, 1999a; Kraus and Pfeife, 1998). Drake et al. (2002) used lidar data to estimate tropical forest structural characteristics. This research utilized an airborne lidar system for obtaining data about the FDP in the Fu-shan Nature Reserve site, and the technique for deriving forest canopy height was investigated. To assess the capability of lidar in estimation of forest canopy height, the height measurements derived from lidar data were compared to the results generated from photogrammetric procedures.

2. MATERIALS AND METHOD

2.1 Study area

The study area for this research is located near the Fusan Experimental Forest of Taiwan Forestry Research Institute (TFRI). The experimental forest is located at 24°46’N, 121°43’E. The elevation of the experimental forest ranges from 400 to 1,400 meters with a total area of 1,097 hectares. The annual mean temperature is 20°C, and the annual mean precipitation is 2,900 mm (TFRI, 2006).

2.2 Data

2.2.1 Lidar data: A Leica ALS50 airborne laser scanner mounted on an airplane was used to acquire data for the study area on June 17, 2006. The sensor was equipped with an aircraft position and orientation system (POS), which recorded the aircraft position and attitude information using a GPS receiver and IMU (inertial measurement unit). The POS data were processed using a proprietary software to generate WGS84 ground coordinates of all the reflected laser pulses. Some important Characteristics of the ALS50 are shown in Table 1 (Leica Geosystems, 2003).

Table 1. Characteristics of ALS50 system

Swath width	up to 75°	
Scan rates	up to 70 Hz	
Number of returns	up to 3 returns	
Pulse rates	up to 52 kHz	
Wavelength	1064 nm	
Altitude (AGL)	500 to 4000 m	
Horizontal accuracy	below 1 m	
Vertical accuracy	15 cm	

2.2.2 Aerial photographs: In addition to the ALS50 system, a Rollei Aerial Insustrial Camera (AIC) mounted on the aircraft was used to obtain photographic imageries of the study area in parallel with laser scanning. Table 2 shows the specifications of the AIC system.

Table 2. Specifications of Rollei Aerial Insustrial Camera

Sensor	CCD-chip with 4080 x 5440 pixels	
Effective sensor size	36.9 x 48.7 mm	
Image	48 bit color depth, 32 MB per image	
Capture rate	3 sec/image	
Sensitivity	ISO 50 to 400	
Pixel resolution	9 µm	
Lens	PQS metric lens, fastest shutter speed: 1/1000 sec, between 50 mm and 500 mm	

2.2.3 Field data: During 2003-2004, the research team of the 25-hectare Fu-shan Nature Reserve FDP site completed the first census of the trees within the site. Based on a standard protocol followed by all the FDP sites of the CTFS program, every tree with DBH (diameter at breast height) larger than 1cm was measured and tagged. The species of each tree was identified, and the DBH and location of the tree was measured. A total of 114,508 trees was recorded, which belong to 110 species. In addition, a total of 1,705 ground points within the FDP were sampled, and the elevations of these points were measured using a total station. These ground points were used to construct a TIN (triangulated irregular network) model and subsequently a 1-meter DEM (digital elevation model) were derived from the TIN model. Figure 1 depicts the TIN model of the FDP site.

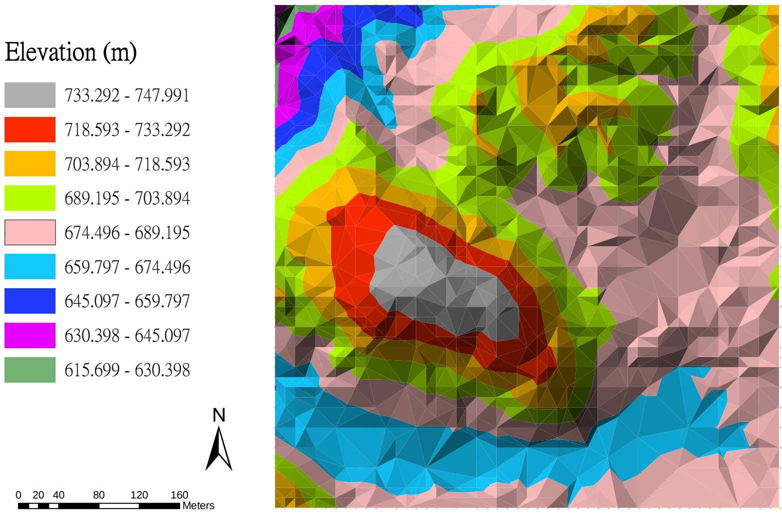

Figure 1. The TIN model of the FDP site

2.3 Methods

A filtering process was performed to extract ground points and surface points from the lidar point clouds data using TerraScan software. To assess the results of the filtering process, the ground points data were compared to the field measurements, and the surface points data were compared to the DSM (digital surface model) derived from photogrammetric procedure.

Originally, the field measurements were recorded in a local coordinate system. In order to compare with the data obtained using lidar and aerial photographs, the field data were transformed to the same coordinate system as that of the lidar and photogrammetric results. By using ESRI ArcGIS software, a geographic database was built using field data. Subsequent analyses were mainly done in ArcGIS environment.

3. RESULTS

The airborne lidar data points were grouped into 5 m x 5 m grid cells, within each cell statistical analysis was performed, and the maximum height and minimum height within each cell was determined. Assuming that the minimum height represents the ground elevation, and the maximum height represents the canopy surface height, we derive DEM and DSM from lidar data, which are shown in Figure 2 and Figure 3, respectively.

Figure 4 shows the ortho image produced from aerial photographs. A DSM was also produced from photogrammetric procedure (Figure 5). The DSM derived from lidar data and photogrammetric procedure both show similar spatial pattern. Figure 6 and Figure 7 depict section views drawn from the lidar point clouds.

Fig. 2. DEM created from airborne lidar data

Fig.3. DSM created from airborne lidar data

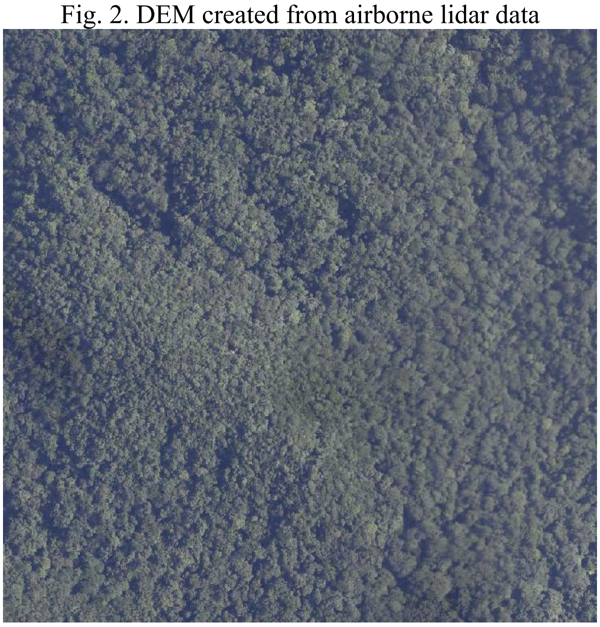

Fig. 4. Ortho image produced using aerial photographs

Fig. 5. DSM produced from aerial photos

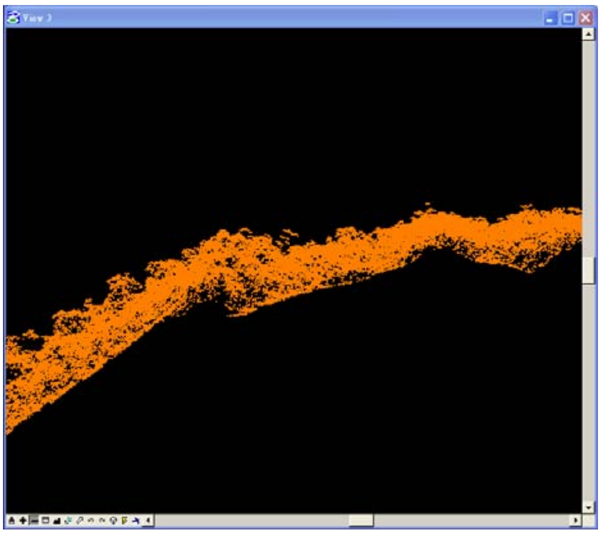

Figure 6. A section drawn from the lidar point clouds

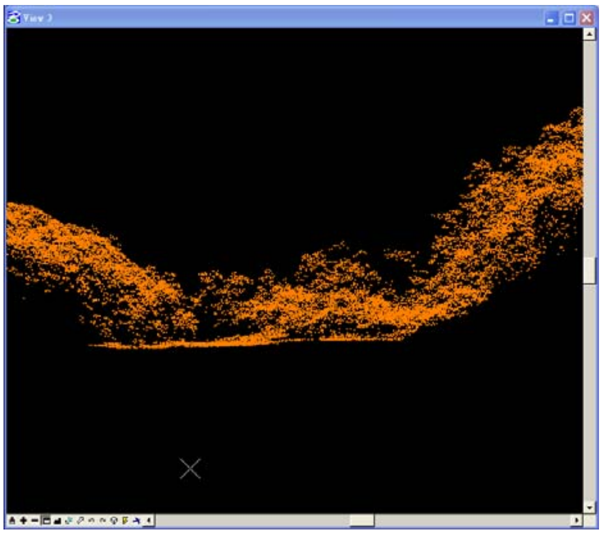

Figure 7. A closer look of the lidar point clouds

4. CONCLUSIONS

The profile of the lidar data clearly shows the forest canopy structure and terrain relief. However, due to dense vegetation cover, it is difficult to extract true ground points from the lidar data. More analysis is needed to improve the accuracy of the classification results. While a more complete analysis is needed to evaluate the accuracy of estimation of forest canopy height, the results indicate that the lidar data have great potential for measuring forest canopy structure directly. Further study will be focused on validation of the predicted lidar canopy height with field survey data, and methodology for integrating photogrammetric data with lidar data to improve the accuracy of classification results as well as canopy structure modeling.

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