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A GIS-BASED ALGORITHM TO GENERATE A LIDAR PIT-FREE CANOPY HEIGHT MODEL

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Key words: GIS, LIDAR, CHM, LAStools, "pit-free"

Abstract: Lidar has provided significant benefits for forest development and engineering operations and provides a good means to collect information on forest stands.

A common analysis using LiDAR data computes the CHM as a difference between DSM and DTM, create a DTM from the ground returns and a DSM from the first returns and subtract the two rasters, but how exactly are generated the DTM and the DSM. Irregular height variations, called data pits are present in the CHM and appear when the first Lidar return is far below the canopy. The purpose of this study is an approach that computes the CHM directly from height-normalized LiDAR points.

1. Introduction

LiDAR (Light Detection and Ranging) is an active remote sensing system which transmits pulses of laser light toward the ground by means of a scanning mirror. The time between sent and reflected pulses is measured and converted into a distance measurement, which is used for derivation of a 3D elevation surface (Popescu, 2007; Lewis and Hancock, 2007). A pulse generated by a LiDAR system is in the near infrared or visible part of the electromagnetic spectrum (900 – 1064 nm) and can penetrate the vegetation canopy during data acquisition (Evans et al, 2009).

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The capability of LiDAR systems to provide height measurements allows us to derive the vertical extent of forest stands. Using this capability, various methodologies have been developed for extracting biomass using both discrete-return and full waveform LiDAR systems (Lefsky et al, 2001; Bortolot and Wynne, 2005; Popescu, 2007; Edson and Wing, 2011). Discrete-return LiDAR systems have a small footprint (typically 20 – 80 cm in diameter) and are able to record one to several returns through the forest canopy depending on the laser energy intensity returned to the sensor. In contrast, waveform sensors have larger footprints (10 – 100 m) and digitize the complete waveform of each returned pulse in fixed distance intervals (Evans et al, 2009; Lewis and Hancock, 2007).

Recently, advancements in technology have allowed for the acquisition of very high resolution three-dimensional point clouds that can be used to map the forest in a virtual environment.

A digital elevation model (DEM) represents height information without any specifications as to the surface and is used as a generic term for digital surface model (DSM) and digital terrain model (DTM) (Peckham, 2007). A DTM, which represents the bare ground surface without any objects like plants and buildings, was derived by building a geodatabase of terrain from all points in the ground class and converting it to a raster format with a cell size of 3 m. Lidar-derived Canopy Height Models (CHMs) are commonly used for extracting relevant forest information.

2. Methods

Site Description: The study area is located in Frumosu, Suceava, Romania nestled at elevation 800 m – 1130 m. In most cases forest stands were dominated by coniferous species with rare occurrence of deciduous or mixed species. The landscape is heavily dominated by a tree species known as Picea abies. (Fig. 2)

To manage, visualize, process and analyze airborne LiDAR data and optical imagery, two commercial software packages were used: ESRI ArcGIS 10.4.1 and LAStools (Version 160110; Isenburg, 2015).

LiDAR Data Processing: The first stage normalizes the height of the Lidar data by replacing the elevation, the original z coordinate of each point with its vertical height above the ground. The pre-processing was implemented in ArcMap and the lasheight modules of LAStools. The second stage constructs a standard CHM from all first returns and – most importantly – a number of partial CHMs from only those first returns that correspond to higher-up vegetation hits. The idea is to compute the shape of the canopy at different levels: low vegetation (0.5 m <height ≤2.0 m), medium vegetation (2.0 m <height ≤10.0 m), and high vegetation (10.0 m <height). All first return points were used to construct the

standard CHM that other researchers have typically generated from the first return lidar points.

Fig. 1 - The forest predominantly consists of Picea abies

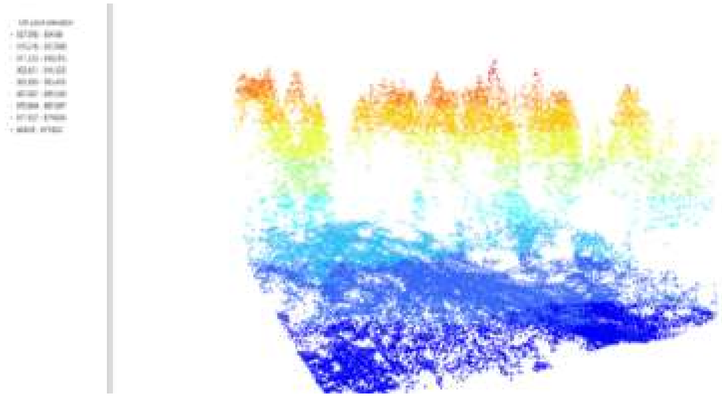

Fig. 2 - LAS point elevation

A Digital Surface Model (DSM) is created from first returns of the LIDAR point cloud data. An above ground surface model is created by removing bare earth elevations from the DSM. Tree canopy are differentiated in the above ground surface model using different morphological filters, color infrared imagery and other ancillary data sources in a knowledge based classification system. Work with digital terrain model (DTM) & digital surface model (DSM) raster files. Create a canopy height model (CHM) raster from DTM & DSM rasters. Canopy Height Model (CHM) is a difference between Digital Surface Model (DSM), being developed from first returns and Digital Terrain Model (DTM) created from the ground returns. The canopy height model (CHM), represents the heights of the trees on the ground. We can derive the CHM by subtracting the ground elevation from the elevation of the top of the surface (or the tops of the trees).

The accuracy and quality of a CHM improves with higher point density LIDAR data. LiDAR canopy height models (CHMs) can exhibit unnatural looking holes or pits, i.e., pixels with a much lower digital number than their immediate neighbors. That not only result in a noisy appearance to the CHM but may also limit semi-automated tree-crown delineation and lead to errors in biomass estimates. Data pits are typically visible in raster CHMs as (apparently) randomly distributed dark holes that are digitally represented by exceptionally lower digital height values than their neighbors.

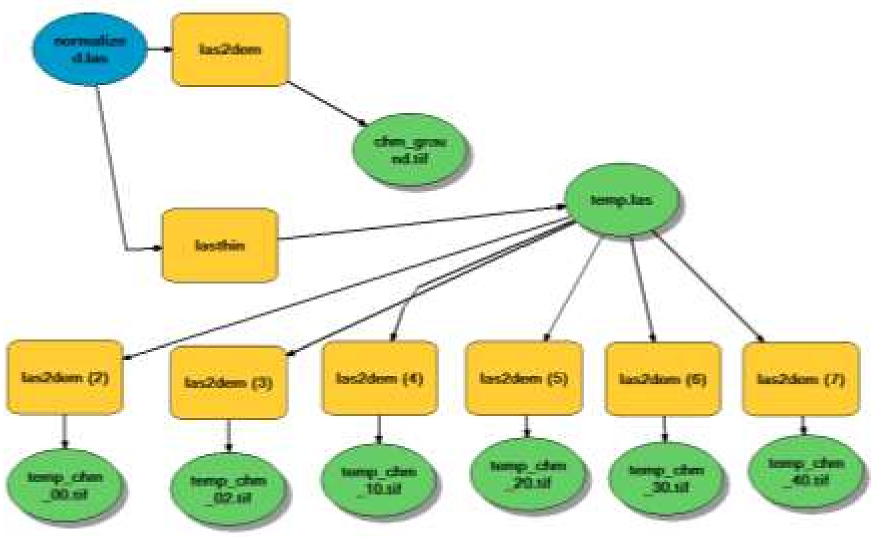

Fig. 3 – Model builder of the pit-free algorithm's work-flow

The purpose of this study is to report on a pit filling method for LiDAR CHM's had brought into the spotlight the need of a databases for optimal exploitation.

The partial CHM raster were generated by triangulating only those first returns with a height. It was determined a grid size of 0.15 m in the CHM and a 0.45-meter optimal rasterization threshold. A pit-free CHM raster was created by combining the partial CHM.

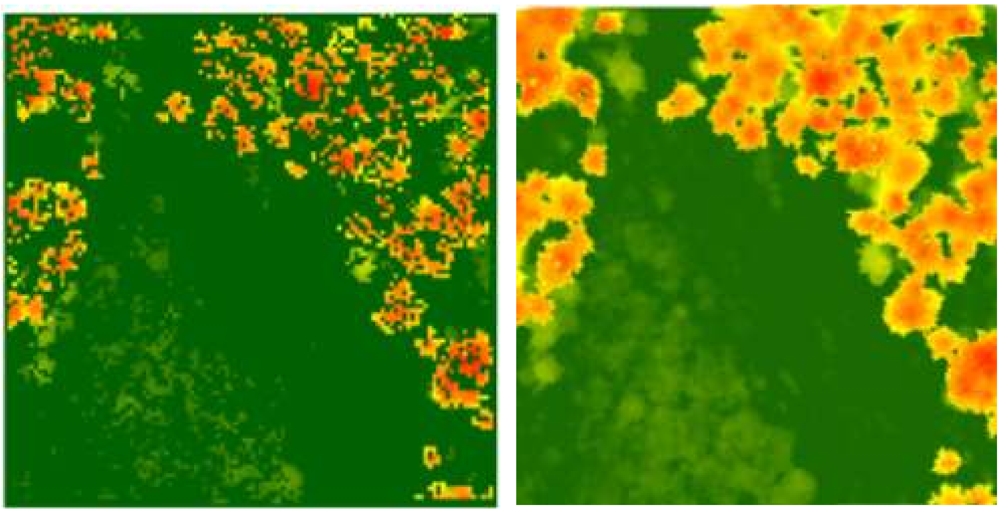

Fig. 4 - The performance of the pit-free algorithm compared with the standard CHMs

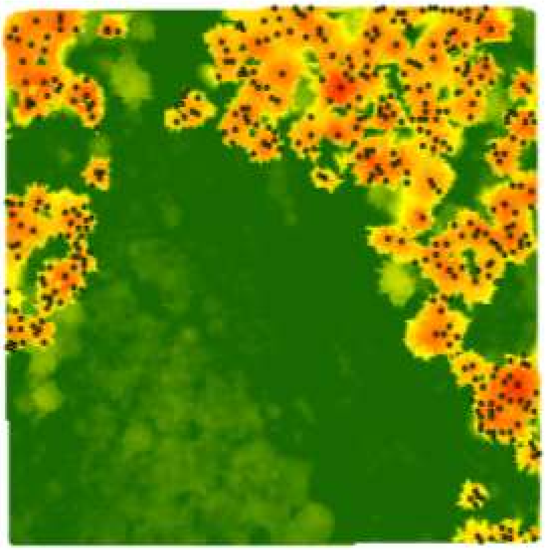

Fig. 5 - The local maxima to points overlaid in the CHM

A canopy height model (CHM) with a resolution of 0.5 m was then developed over the study areas. Taking the CHM as an input, pixels with elevation values greater than or equal to 5 m were extracted. The maximum value in a 3 m x 3 m cell was obtained and the output raster was calculated using the formula:

LM=Con (CHM==FS, CHM)
where
Con=conditional function;
CHM=Input;
CHM FS=maximum values in a 3 m x 3 m cell; LM=local maxima.

The output of the local maxima raster was converted into points.

Irregularities in canopy surface elevation, also called "data pits," form a challenging problem due to their disruptive influence on a CHM, reducing accuracy in tree detection and subsequent biophysical measurements (Ben-Arie et al., 2009; Gaveau and Hill, 2003; Zhao et al., 2009).

The result indicates that the hole-free algorithm is particularly successful for low-density Lidar data such as our artificial data, which corresponds to a small footprint laser beam that lowers the canopy with low density.

Conclusions

The airborne light detection and ranging (LiDAR) has already been widely used in forest inventory investigation with the advantage of obtaining multiple forest information. The canopy height model (CHM) derived from LiDAR data is a key model, which is used frequently to retrieve forest parameters, such as the tree height, crown width, diameter at breast height, crown density, volume and biomass and so on. The result demonstrates that our algorithm is able to efficiently remove all irregularities in the canopy surface from LiDAR data sets. The "pit-free" CHM algorithm can easily be implemented with LAStools or by executing the LAStools Pipelines distributed with the toolboxes for ArcGIS and QGIS.

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