A COMPARISON OF LIDAR AND IMAGE-DERIVED CANOPY HEIGHT MODELS FOR INDIVIDUAL TREE CROWN SEGMENTATION WITH OBJECT BASED IMAGE ANALYSIS

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1. Introduction

The value of airborne LiDAR for detailed forest inventory has been well documented at both plot and single tree scales (Koch et al., 2006; Wulder et al., 2012). Among many advantages of Airborne Laser Scanning, such as high accuracy of tree height and stand volume estimations (Lefsky et al., 2002; Lim et al., 2003; Zhao et al., 2009), the lack of multispectral information is a factor of consideration. Recent improvements in digital photogrammetry, especially the possibility to generate Canopy Height Models (CHM) by means of automatic image matching (Semi-Global Matching, SGM), are considered a less costly alternative to LiDAR point clouds (White et al., 2013).

Accurate tree crown segmentation is important for single tree based inventories, and there is a number of approaches that result in creating individual tree crowns (Vauhkonen et al., 2011). However, in many cases, these algorithms are only suitable for ALS data with high point densities or image-derived CHMs. Additionally, the algorithms are typically designed for mature, conifer trees.

The aim of this study was to create a more universal algorithm suitable for performing crown segmentation for different types of forest stands, varying in tree species composition and age, and applicable to different types of input data, including LiDAR point clouds or digital airborne imagery. The authors also aimed to make the algorithm self-adapting for a variety of forest stand conditions.

2. Methods

In order to develop an algorithm that is applicable under a variety of stand conditions, we chose multiple 200 x 200 m plots located in forest stands composed of different species and a range of tree dimensions. The study area was located in Saxony, South East Germany. The forest stands were dominated by Norway spruce (*Picea abies*) of different age classes.

We used two types of spatial data for the Object Based Image Analysis (OBIA) approach: (1) ALS point cloud data (first/last pulse with low density < 2pts/m^2; (2) digital aerial photos acquired with VEXCEL UltarCam X camera, 4 Bands (RGBI) with 16bit resolution and a GSD of about 0.20 m.

LiDAR point clouds were first filtered, then classified, normalized and rasterized to create the necessary Canopy Height Models (CHM).

We generated a DSM model from aerial stereo photographs using the software package RSG (Remote Sensing Graz), which was developed by Joanneum Research in Graz, Austria (Schardt et al., 2006, Hirschmüller, 2008). In a complex workflow, RSG is geocoding and correlating aerial stereo-pairs (or triplets) in order to produce a map of disparities between the search and reference images as a first result of several forward- and backward-matching steps. Finally, the disparity information is used to calculate the correct coordinates of the natural surface, resulting in the final Digital Surface Model (DSM).

Although RSG includes algorithms to calculate digital terrain models (DTM) from the DSM, the accuracy and representativeness of such DTM's are not sufficient to calculate a precise crown height model (CHM). This is mainly due to the fact that the ground under the forest canopy is often not sufficiently visible on the aerial photographs. Because of that, the entire process of individual tree detection still relies on DTM's generated from the filtered ALS point cloud, which best represents the ground under the forest canopy.

The process of defining the proper crown shape involves three major stages. First, the homogenous forest stand polygons were defined based on their height. This allowed us to parameterize the processing differently for each height-group and create smaller, denser crown polygons for shorter trees, and create larger, more spaced polygons for taller trees.

Treetops were then located on the CHM raster layer using local maxima search, separately for each homogeneous stand polygon. Using a region growing approach, the crown edges were determined. In this multi-stage process, each treetop is first surrounded with candidate pixels and their height is compared to the height of the treetop. The candidate is then assigned to class "crown", if the height difference is within the specified threshold. The process is repeated a number of times, with previously assigned crown pixels becoming surrounded with new adjacent candidate pixels. The process ends when a generated crown segment reaches the border of another segment or when the height difference condition cannot be fulfilled anymore.

3. Results

The single tree detection accuracy achieved on ALS- and SGM-derived canopy models was equal to 90.1% and 74.1%, respectively. Tree crowns detected on SGM models contained more than one reference treetop in 14.3% cases, whereas for ALS data this value equals 2.9%. The rate of not detected crowns was equal to 6.8% for ALS and 11.5% for SGM data, respectively.

Visual assessment of the results for one of the sample plots (Figure 1) provides a good insight into differences between two canopy height models and the delineation methods itself. For both ALS (A) and SGM-derived (B) input canopy models, the algorithm generated crown polygons that correspond to their size and shape. However, the results on ALS data were visibly more accurate, with SGM-derived tree crown polygons often containing more than one tree crown..

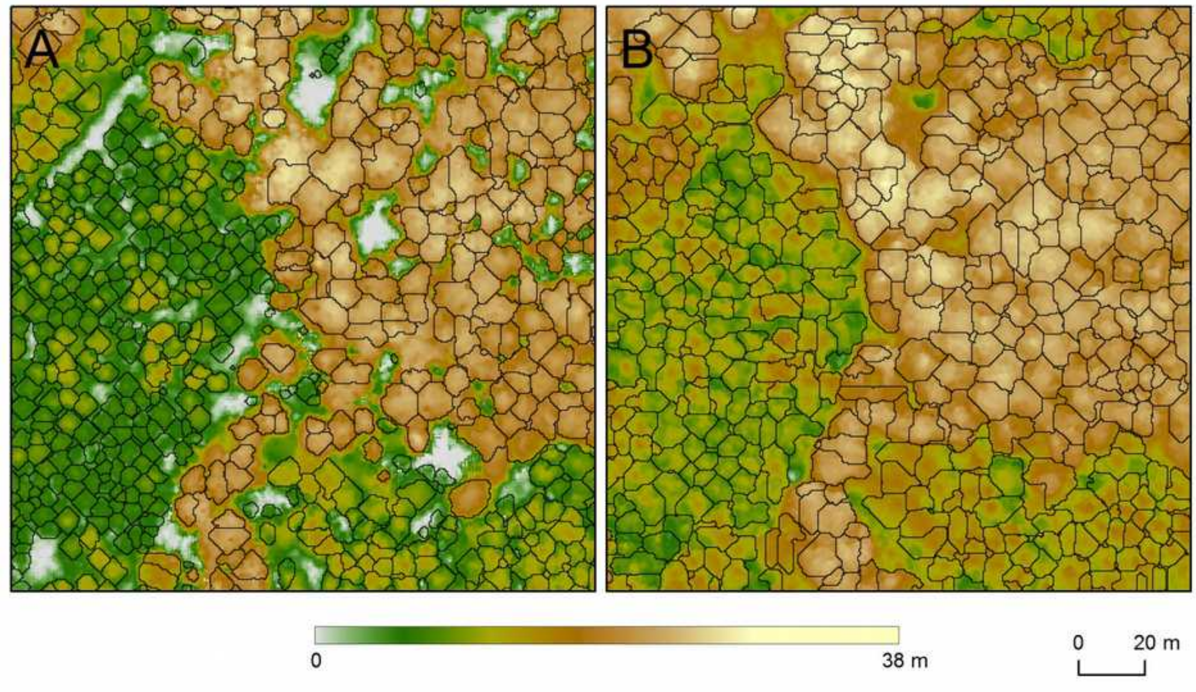

Figure . Tree crown delineation result on one of 200 x 200 m sample plots. A – CHM based on ALS LiDAR data. B – CHM based on SGM on aerial stereopairs.

4. Discussion

The lower accuracy achieved for the SGM-derived model is due to the lower quality of the CHM. Canopy models created with SGM typically have a smoothed top surface and are often unable to correctly represent gaps in the canopy (Hirschmugl et al., 2007; White et al., 2013). LiDAR data, on the other hand, was much more suitable for creating highly accurate single tree crown polygons. The initial processing step of dividing the forest stand into homogenous groups that allow application of different parameters modifying the delineation steps was crucial for achieving reliable results across different forest stand conditions.

The accuracy of the tree crown delineation depends much more on the quality of the data being used, such as the ALS point density or the overlapping percentage of the aerial images, than on the methodological approach itself. The differences in quality between LiDAR- and SGM-derived CHM's should be considered when comparing the costs of the two approaches for tree extraction.

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