EXTRACTION OF TREE CROWNS AND HEIGHTS USING LIDAR DATA

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***Abstract**: Nowadays LIDAR data is widely used in different field and provides a good means to collect information on forest stands. Light Detection and Ranging (LIDAR) is active remote sensing which uses laser lights to strike features and record the reflected pulses to generate the 3D model of objects and offers another source of information for tree detection. This paper presents Inverse Watershed segmentation, a new method for tree detection, where individual trees are detected based on the densities of high points which distinctively separates crown centers from crown edges. This method treat raster like a watershed using focal flow to determine local maxima (tree heights) and watershed delineation (tree crowns).*

***Keywords:** LIDAR, Inverse Watershed segmentation, tree detection*

1. Introduction

Lidar stands for light detection and ranging. In its most common form, it is an airborne optical remote-sensing technology that measures scattered light to find range and other information on a distant target. Similar to radar technology, which uses radio waves, the range to an object is determined by measuring the time delay between transmission of a pulse and detection of a reflected signal. Instead of radio waves, lidar uses much shorter wavelengths of the electromagnetic spectrum, typically in the ultraviolet, visible, or nearinfrared range. This technology allows the direct measurement of three-dimensional structures and the underlying terrain. Depending on the methodology used to capture the data, the resultant data can be very dense, for example, five points per meter. Such high resolution gives higher accuracy for the measurement of the height of features on the ground and above the ground. The ability to capture the height at such high resolution is LIDAR's principal advantage over conventional optical instruments, such as digital cameras, for elevation model creation.

Also, captured by the lidar sensors is the intensity of each return. The intensity value is a measure of the return signal strength. It measures the peak amplitude of return pulses as they are reflected from the target to the detector of the lidar system. Intensity is often used as an aid in feature detection and, where conventional aerial photography is not available, can be used as a pseudoimage to provide context of the lidar acquisition area.

Foresters use light detection and ranging (lidar) data to understand the forest canopy and terrain, which helps them with forest management and operational activities.

Lidar has provided significant benefits for forest development and engineering operations including locating roads, harvest planning, forest regeneration, and more. The ability to identify suitable creek crossings, determine optimal routes, and locate previously unmapped historic roads aids in reducing costs and creating operational efficiencies.

For forest inventory activities, lidar has been used primarily to retrieve basic structural tree attributes including height, canopy cover, and vertical profiles. These attributes can be used to derive other critical forestry measurements including basal area and timber volume, as well as biomass for alternative energy and carbon sequestration analysis.

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).

To obtain single-tree information from remotely sensed data, regardless of aerial photographs, satellite imagery, or LiDAR, it is essential to detect and delineate individual trees. Early attempts at the detection and delineation of individual trees using remotely sensed data were carried out with multispectral imagery (Koch et al. 2006).

Several methods have been applied, to delineate individual trees using such imagery including multiple scale edge segmentation (Brandtberg and Walter 1998), template matching (Pollock 1996), watershed segmentation (Schardt et al. 2002), and local maxima filtering (Dralle and Rudemo 1996).

It was assumed the delineation of tree crowns could be accomplished using imagery, since the center of a crown (peak) in the image is brighter than the edge (valley) (Wulder et al. 2003). However, the difference in the reflectance value between the center and edge of the crown is not always distinct, due to influencing factors such as the crown spectral property, complicated crown texture, diverse forest structure, and time of imagery acquisition (Wulder et al. 2003).

Leckie et al. (2003) applied the valley-following method whereas Brandtberg et al. (2003) carried out crown segmentation by using multiple scale edge segmentation. Persson et al. (2002) attempted tree delineation using local maxima detection, and Mei and Durrieu (2004) segmented tree crowns using watershed segmentation with LiDAR data.

To decrease these errors, Popescu and Wynne (2004) accomplished tree segmentation using the local maxima detecting method by adopting flexible window sizes according to the relationship between the tree height and crown size. As another method for improving the accuracy of delineated individual trees, Chen et al. (2006) presented marker-controlled watershed segmentation, which performs watershed segmentation around user-specified markers in the input image, rather than the local maxima, to remove false tree tops.

A watershed is an area that drains surface water to a common outlet. Watershed analysis refers to the process of using DEMs (Digital Elevation Models) and raster operations to delineate watersheds and to derive topographic features such as stream networks (Kang, 2008). Previously, watershed delineation was mainly conducted by the method of hand delineation.

The watershed boundary can be determined using contour line map, hydrological regime, by calculation procedure and dot grid by a planimeter. In order to successfully delineate the watershed boundary, the evaluator needs to visualize the landscape as represented by each of the contour lines in the map. The steepness of the area which can be determined from the contour interval is related to the water flow.

The techniques used for delineation of the watershed boundary by surface drainage are ultimately dependent on topographical information generated in a local neighborhood on the DEM. The raster data used in GIS carry spatial information and one of it is the coordinate of the earth surface. With the information of contour lines and river layer, it is enough for the GIS to manipulate it to determined the watershed area and delineate the boundary. Advances in the analysis of flow direction and flow networks from DEMs have led to several automated methods for watershed and stream delineation (Jenson and Domingue, 1988; Tarboton, 1997). The simple rule in this exercise is simplicity where the operation is transparent when an operator can examine its source code and comprehend how it works. It is simple when its operation is sufficiently, uncomplicated that a programmer can visualize with little effort of all the potential situations that it might encounter.

2. Methodology
Study area and description

The study area is located at 38.756065 N latitude and -9.152747 W longitude and it is situated at elevation 45 meters above sea level in Lisbon, Portugal.

Campo Grande Garden is the largest garden center of Lisbon, occupying an area of 11.1 hectares, reaching 1,200m long by 200m wide. The garden is divided into two areas, the Av of Brazil:. North zone with 6ha and the South zone with 5ha. It is located in the parish of Alvalade, the road known as Campo Grande, as shown in Fig. 1.

In the garden we can find the most diverse botanical specimens, some quite rare as palm Canarian pine, eucalyptus, acacia, mulberry paper, fig trees, pepper trees, lime trees, frankincense, rosewood, grevídea, maple and chestnut red India, etc. Also many species of nesting birds and can be observed, including goldfinches, sparrows, the gimmicks, the carrasqueiras warblers and kingfishers rocks. Situated in the valley of the river Lumiar (tributary of the Alcantara river), the garden is rich in basalt.

Fig. 1. Bird’s eye image of Campo Grande Garden (source: http://scrif.igeo.pt)

Methods

LiDAR data

In this study was used for acquisition of the LiDAR data from WMS LIDAR the coast of Portugal. Visible from 1:40 000.

The LIDAR data is used to generate Digital Terrain Model (DTM) and Digital Surface Model (DSM) in grid form. Using the DTM and DSM generated from the lidar data, it is possible to estimate the canopy height above the ground. To calculate the canopy height, simply subtract one surface from the other by using the Minus tool found in the ArcGIS Spatial Analyst toolbox (ArcToolbox\Spatial Analyst Tools\Math\Minus). We subtract the DTM from DSM to generate the normalized DSM (nDSM). In which, the nDSM represents the above ground surface that is used to separate the ground and above ground objects.

The watershed transformation is a powerful partitioning tool for a gray-scale image. Due to the similarity between the DSM and gray-scale images, the watershed transformation is also useful for delineating single trees from the DSM (Chen et al. 2006).

Watershed segmentation applies mathematical morphology to explore the geometric structure of trees in an image. The advantages of this approach are that the method may selectively preserve structural information while accomplishing desired tasks on the image. In the region-based approach, homogeneity regarding the shape and color in the neighborhood is examined in a region growing process. The contour-based approach minimizes the internal energy by weighting the parameters (L. Chen et al.).

Methodology in ArcMap is to treat raster like a watershed, use focal flow to determine local maxima (tree heights) and watershed delineation (tree crowns).

First, we apply watershed segmentation method on DSM, was prepare feature height raster, make data size manageable and imitate a watershed, invert surface, tree peaks become "ponds" and tree branches become watersheds.

In the second step, find tree peaks using low filter to smooth inverted raster, determine local minima using focal flow, extract tree peaks and remove low vegetation.

To find the tree crowns was created a mask to make tree peaks null data, mask the inverted raster to prepare to fill sinks, create a flow direction surface and create watersheds.

In the last step was calculated the area and the tree crown attributes. The process of extracting hydrological information is showing in Fig. 2 and Fig. 3.

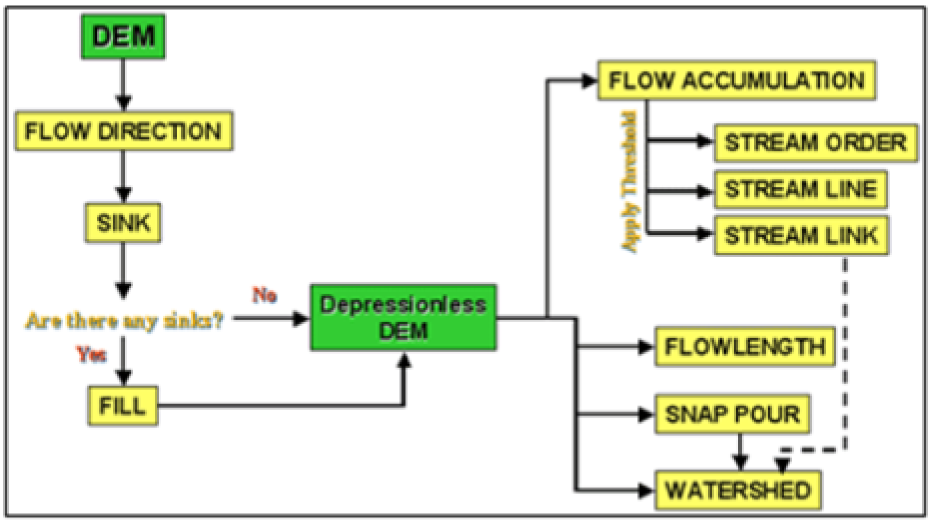


Fig. 2. The process of extracting hydrological information

There are three basic steps in watershed segmentation, which is the value of CHM will be reversed from the highest to the lowest value, then the flow direction of the reverse CHM will be determined, and the basin method has been applied to generate polygons according to the watershed lines, that assumes water flows to downwards that act as an individual watershed or tree crown. (L. R. Jamru)

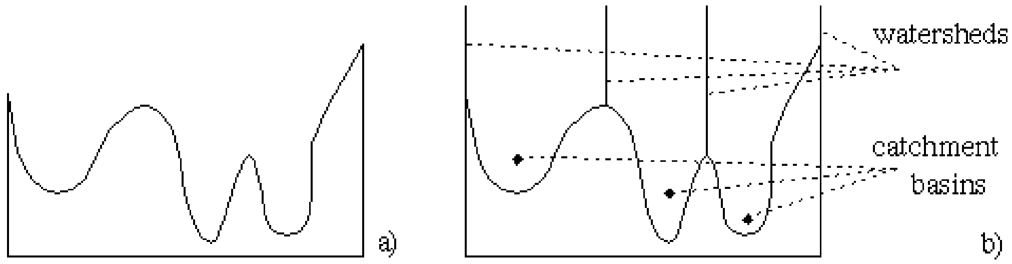
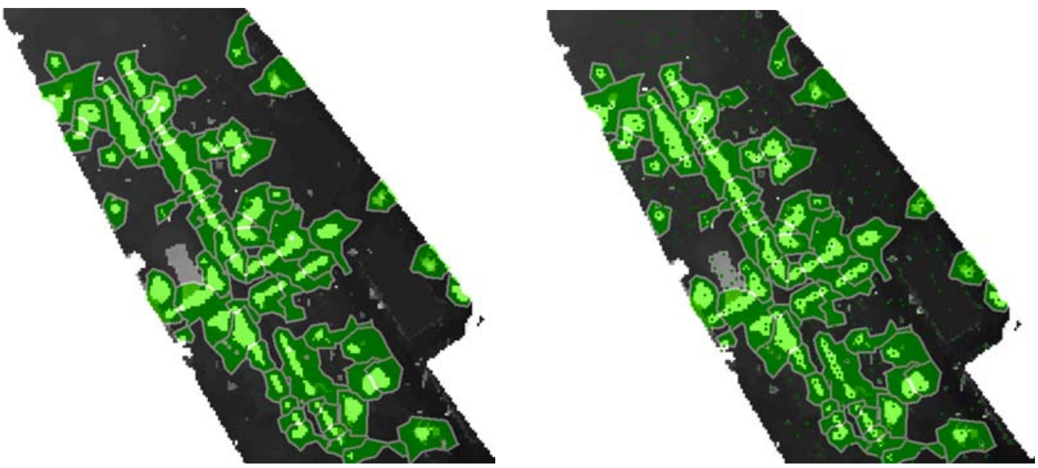


Fig. 3. a) Gray level profile of image data. b) Watershed segmentation – local minima of gray level (altitude) yield catchments basins, local maxima define the watershed lines.

a) b)

Fig. 4. Data description. (a) aerial photo. (b) Invert surface



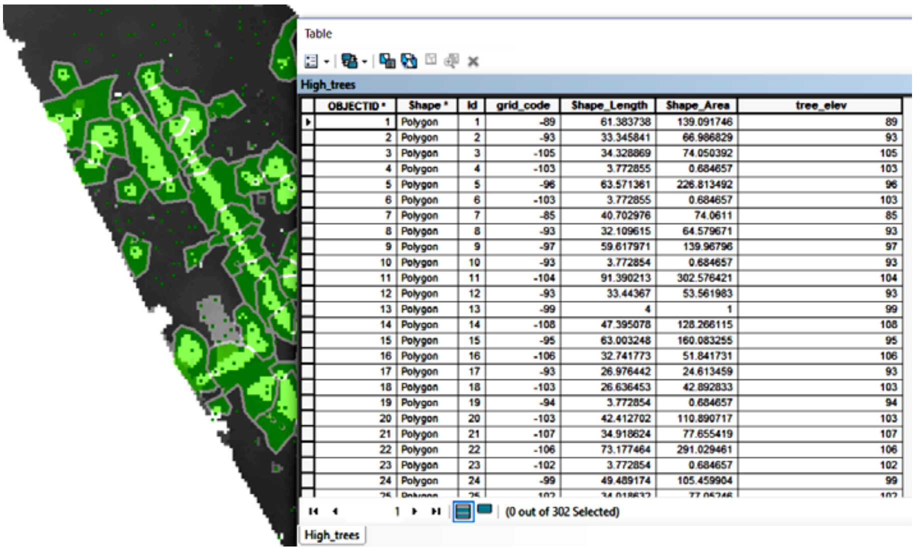
a) b)

Fig. 5. Flowchart of the tree crown extraction: a) Segmentation of LIDAR data. b) Local Maximum Search

Watershed segmentation method can find the changes of individual tree height, so we can extract the boundary of each individual tree. We assume that the maximum point in the boundary is the tree position. Local maximum filter is applied to extract the tree position, as shown in Fig. 4 and 5. The forest parameters for each tree crown include tree position and height.

Lidar data can play an important role for small scale forest inventories, especially for deriving tree heights and stand volume.

After segmentation, we perform the object-oriented classification to determine the tree regions. We use the extracted tree regions in the individual trees extraction. Assuming that the highest point in the boundary is a treetop, one segmented boundary is selected to represent one tree crown.



OBJECTID *	Shape *	Id	grid_code	Shape_Length	Shape_Area	tree_elev
1	Polygon	1	-89	61.383738	139.091746	89
2	Polygon	2	-93	33.345841	66.986829	93
3	Polygon	3	-105	34.328869	74.050392	105
4	Polygon	4	-103	3.772855	0.684657	103
5	Polygon	5	-96	63.571361	226.813492	96
6	Polygon	6	-103	3.772855	0.684657	103
7	Polygon	7	-85	40.702976	74.0611	85
8	Polygon	8	-93	32.109615	64.579671	93
9	Polygon	9	-97	59.617971	139.96796	97
10	Polygon	10	-93	3.772854	0.684657	93
11	Polygon	11	-104	91.390213	302.576421	104
12	Polygon	12	-93	33.44367	53.561983	93
13	Polygon	13	-99	4	1	99
14	Polygon	14	-108	47.395078	128.266115	108
15	Polygon	15	-95	63.003248	160.083255	95
16	Polygon	16	-106	32.741773	51.841731	106
17	Polygon	17	-93	26.976442	24.613459	93
18	Polygon	18	-103	26.636453	42.892833	103
19	Polygon	19	-94	3.772854	0.684657	94
20	Polygon	20	-103	42.412702	110.890717	103
21	Polygon	21	-107	34.918624	77.655419	107
22	Polygon	22	-106	73.177464	291.029461	106
23	Polygon	23	-102	3.772854	0.684657	102
24	Polygon	24	-99	49.489174	105.459904	99

Fig. 6. Tree crown attributes

The estimation of tree height is advanced following the development of LiDAR technique. The estimation model of tree height considering suppressed trees is developed in order to extract tree height accurately using LiDAR data.

The experiment results indicate that the watershed segmentation method based on is an effective method to extract the boundary of trees.

However, general watershed segmentation methods have problems in that the number of individual trees may be overestimated or underestimated due to the large height variation within their topography or smaller tree tops under the crowns of the higher trees.

3. Conclusions

This paper use LiDAR data and constructed the model of finding tree height.

Tree species identification is important for a variety of natural resource management and monitoring activities including riparian buffer characterization, wildfire risk assessment, biodiversity monitoring, and wildlife habitat improvement.

Leaf-off LIDAR data were used to create a digital terrain model for the study area because this laser system was flown with higher point density per square meter and with more overlapped flight line than the system used for leaf-on conditions.

Inverse watershed segmentation IWS is one of the methods commonly used for extraction of forest inventory parameters at an individual tree level from a LiDAR-derived CHM (Edson and Wing, 2011).

There are many researchers explore how to estimate tree height using LiDAR data in recent years, most of them do this using CHM (Canopy Height Model). This CHM is the difference between DSM (Digital Surface Model) and DTM (Digital Terrain Model), which is the height of non-ground objects such as trees, buildings, vehicles etc.

When applied, the inverted canopy surface raster is segmented into the equivalent of individual hydrologic drainage basins by identification of local maximum and the nearest minima values (Andersen, 2009).

In general, the number of trees identified by the CHM segmentation algorithms has not corresponded to the number of trees measured in the field.

LiDAR data can be effectively used for forest inventory, especially for detecting individual trees and estimating tree heights.

The watershed segmentation algorithm is a robust image segmentation tool, which can be used to extract interested objects in the image effectively.

Watershed segmentation method is an effective way to extract canopy objects because which can take advantage of the height difference between trees fully. In addition, the watershed segmentation method is a method without any parameters.

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