Single tree crowns delineation using multireturn ALS data in an Alpine forest

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Keywords: ALS, single tree approach, delineation, forest canopy, understory

Traditionally, forest inventories are based on extensive field work. Acquisition of ground reference data become expensive and time consuming. Remote sensing technologies, like airborne laser scanning (ALS) data are a remarkable source of information for the estimation of forest inventory attributes, such as tree height and stem volume. High point density ALS data allows individual tree crowns (ITC) delineation, and thus forest inventories at ITC level. When dealing with multi-layered forests, a problem is the detection of intermediate and suppressed trees that are covered by dominant ones. Consequently, the number of stems is usually underestimated and the correctly identified trees are often the largest and most dominant trees. This problem becomes evident and more significant when using ITC delineation methods based on normalized Digital Surface Models. In addition, the frequency of the errors depends on the properties of crown detection algorithm, the ALS data, as well as the forest structure. Thus, the challenge of this paper is to develop a new method for ITC delineation using normalized ALS point cloud that can further detect small trees under or next to a dominant tree.

The objective of this paper is to develop an advanced approach for ITC delineation based on raw ALS point cloud. The proposed method is to exploit clustering techniques at both 2D and 3D levels, in order to separate the ALS points into individual trees. In greater detail the method is structured into the following main steps:

1. the area of interest is divided into horizontal layers along normalized Z coordinates;
2. a 3D k-means clustering is applied along all layers;
3. k-means clusters are grouped into 3D clusters using a prolate ellipsoid shape along all layers;
4. a kernel density function is applied to estimate the distribution of points in the 3D clusters along x, y and z axes direction (Figure 1, 2);
5. unevenly distributed 3D cluster points are separated into two new 3D clusters;
6. 3D clusters are merged along all layers in 2D space and grouped into a final 3D clusters;
7. for each resulted cluster, normalized 3D points are given from which single tree parameters are assessed.

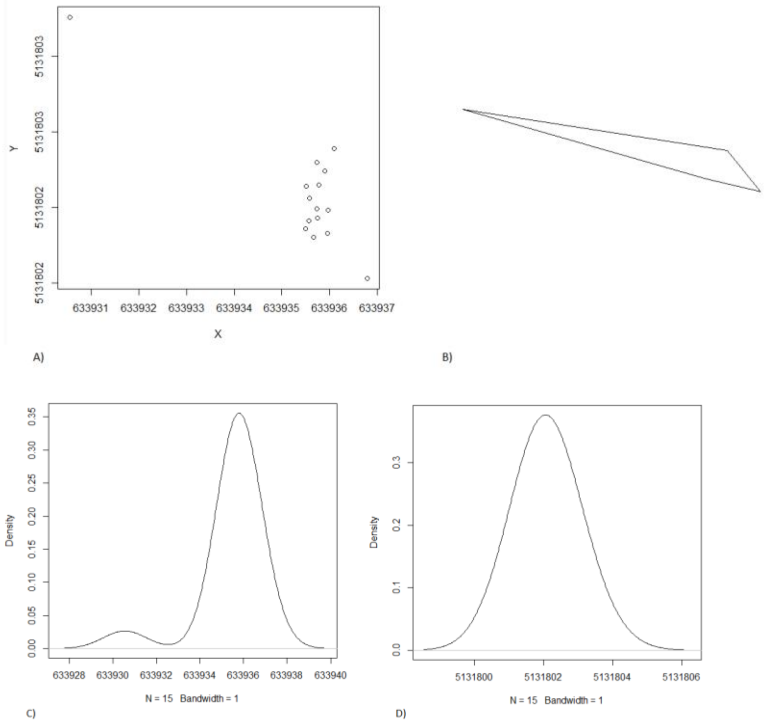

Figure 1: A) Points inside polygon, B) polygon, C) first derivative in x direction and, D) first derivative in y direction.

First derivatives in x and y direction are estimated for each polygon (Figure 1). If in both axis directions one peak is provided, then the polygon remains unchanged. If not, the polygon is splitted into two polygons. This procedure is repeated until all Gaussian distributions have just one peak.

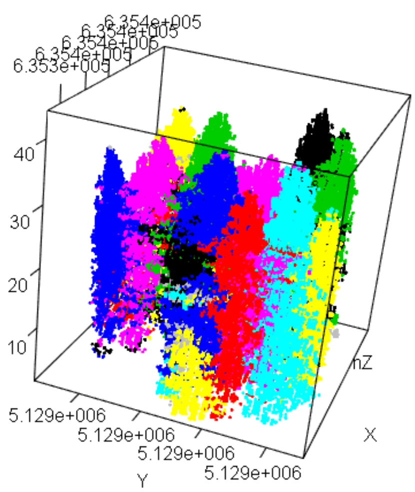

Figure 2: 3D clusters after the estimation of point's distribution, first in y and x axes direction and then in z-axis direction.

The 3D clusters after step 5 (Figure 2) are merged always starting from the top cluster. Clusters are merged if the overlapping area is sufficiently overlapped with the previous cluster

The proposed methodology was tested over a forest area in the Italian Alps, characterized by the presence of both broadleaf and coniferous tree species, with a dominance of Norway spruce. Visual interpretation of preliminary results showed that our method is able to delineate ITC of both suppressed and intermediate trees.