Delineation of forests based on airborne LIDAR data

Eysn, Lothar[1]

Hollaus, Markus[2]

Schadauer, Klemens[3]

Pfeifer, Norbert[4]

[1,2,4] Institute of Photogrammetry & Remote Sensing, Vienna University of Technology, Gußhausstraße 27-29, A-1040 Vienna, Austria, {le,mh,np}@ipf.tuwien.ac.at

[3]Department of Forest Inventory at the Federal Research and Training Center for Forests, Natural Hazards and Landscape, Seckendorff-Gudent-Weg, A-1130 Vienna, Austria, klemens.schadauer@bfw.gv.at

Bulleted list of abstract highlights:

- This paper evaluates a new approach for the automatic delineation of forested areas, based on airborne laserscanning data and criterions of the forest definition of the Austrian national forest inventory.
- A new method for calculating the crown coverage, which is a mandatory criterion in every forest definition, is introduced. The 'tree triples' method, is based on defining CC as a relation between the sum of the crown areas of three neighboring trees and the area of their convex hull.
- The method presented delivers repeatable and objective results. Compared to a manually delineated reference mask, the method presented delivers a Kappa of 0.92 and an overall accuracy of 96 %.
- The results of the approach show the high potential of a fully automatic delineation of forested areas, based on airborne laser scanning.

Extended Abstract:

The delineation of forested areas is a critical task. The resulting maps are a fundamental input for a broad field of applications and users (e.g. governmental authorities, forestry). The results determined from these applications are highly dependent on the fundamental input parameters size and position of the delineated forest areas. The delineation of forests has a long tradition in remote sensing and in the past mainly aerial images were used for a manual or semi-automated delineation. Shadow effects limit this task, particularly for detecting small forest clearings and the exact delineation of forest borders on a parcel level. Additionally, the quality of the results of a manual delineation is subjective and variable

between analysts and may lead to inhomogeneous, maybe even incorrect datasets. An automatic delineation of forested areas based on ALS data can overcome these limitations in most cases [1].

To classify an area as forest or non-forest, different forest definitions are available. Unfortunately most definitions lack precise geometrical descriptions for the different criteria. A mandatory criterion in forest definitions is the criterion of crown coverage (CC), which defines the proportion of the forest floor covered by the vertical projection of the tree crowns [2]. For loosely stocked areas, this criterion is critical, because the reference size and shape, for which the amount of projected crown area is calculated, is not clearly defined in most definitions. Thus current forest delineations differ and tend to be non-comparable because of different settings for checking the criterion of CC in the delineation process. Therefore, this paper evaluates a new approach for the automatic delineation of forested areas with a clearly defined method for calculating CC. The geometrical criteria of the Austrian national forest inventory (min. area, min. height, min. width and min. crown coverage) are used in this approach. Land use criteria are not considered.

The delineation of forested areas is commonly a large area application. Performing this task on a pure ALS pointcloud basis would be very extensive because of the large amount of data. Therefore, the focus of this work was to develop a method based on the rasterized ALS data. Two base products are used for the delineation process. The first one is the canopy height model (CHM), which is derived by subtracting the digital terrain model (DTM) from the digital surface model (DSM). The CHM is a very suitable product for the delineation of forested areas because it directly shows object heights (e.g., tree heights). The second base product is a slope adaptive echo ratio (sER) map [3] which is a measure for local transparency and roughness of the top-most surface and is well suited for the elimination of artificial objects in the forest delineation process.

In this approach, the hierarchy of checking the criterions of the forest definition is defined as follows: (1) min. height, (2) min. CC, (3) min. area and (4) min width. The minimum height criterion is considered by applying a height threshold on the CHM heights. Artificial objects e.g. buildings, which have similar objects heights as forests, are removed in a pre-processing step from the CHM based on the sER map. The criterion of CC is checked with the new approach, the ‘tree triples’ method, which is based on defining CC as a relation between the sum of the crown areas of three neighboring trees and the area of their convex hull (Figure 1 a). The crown areas are estimated by applying a statistical model between crown radius, tree height and elevation. The model is locally calibrated based on automatically extracting sample trees from the ALS data. To obtain the tree heights, tree positions are detected with a local maximum search on the CHM. For each tree position the tree height and elevation is deduced and furthermore the crown area is estimated by using the statistical relation (Figure 1 b). The tree triples are found by applying a Delaunay triangulation to the detected tree positions. Each tree triple is checked against the minimum CC value. Tree triples fulfilling the CC value are kept while triples not fulfilling the CC value are removed. The remaining areas fulfilling the min. height criterion as well as the min CC. criterion are checked against the min. area criterion by using standard GIS queries. Firstly forest gaps smaller than the min. area criterion are filled. Secondly forest areas not fulfilling the min. area criterion are erased. The minimum width criterion of is applied by using morphologic operations (open, close) based on the intermediate result fulfilling the criteria height, CC and area. Narrow forested areas that do not fulfill the criterion are removed. This operation is also related to the area criterion, because the removal of narrow areas leads to changes of the forested areas. Therefore, an iterative process of checking minimum area and width is applied. A final forest mask, considering the mentioned criteria, is delineated by using all previously described processing steps (Figure 1 c).

The approach is applied and analyzed for two study areas in Tyrol, Austria which consist of mainly coniferous trees. The selected areas show a loosely stocked forest at the upper timberline and a fragmented forest on the hillside. The method presented delivers repeatable and objective results and provides a beneficial tool for operational applications. Compared to a manually delineated reference mask, the method presented delivers a Kappa of 0.92 and an overall accuracy of 96%. The 'tree triples' approach provides a clearly defined reference size for calculating CC and overcomes limitations of other calculation methods (e.g. smoothing effects, dependency of the kernel size and shape using a moving window approach) especially in loosely stocked forests. Due to the applied minimum area criterion, too small forest patches are removed, and too small forest clearings are assigned to the forest area. Narrow forest areas are eliminated by applying the minimum width criterion. The results of the approach show the high potential of a fully automatic delineation of forests based on airborne laser scanning.

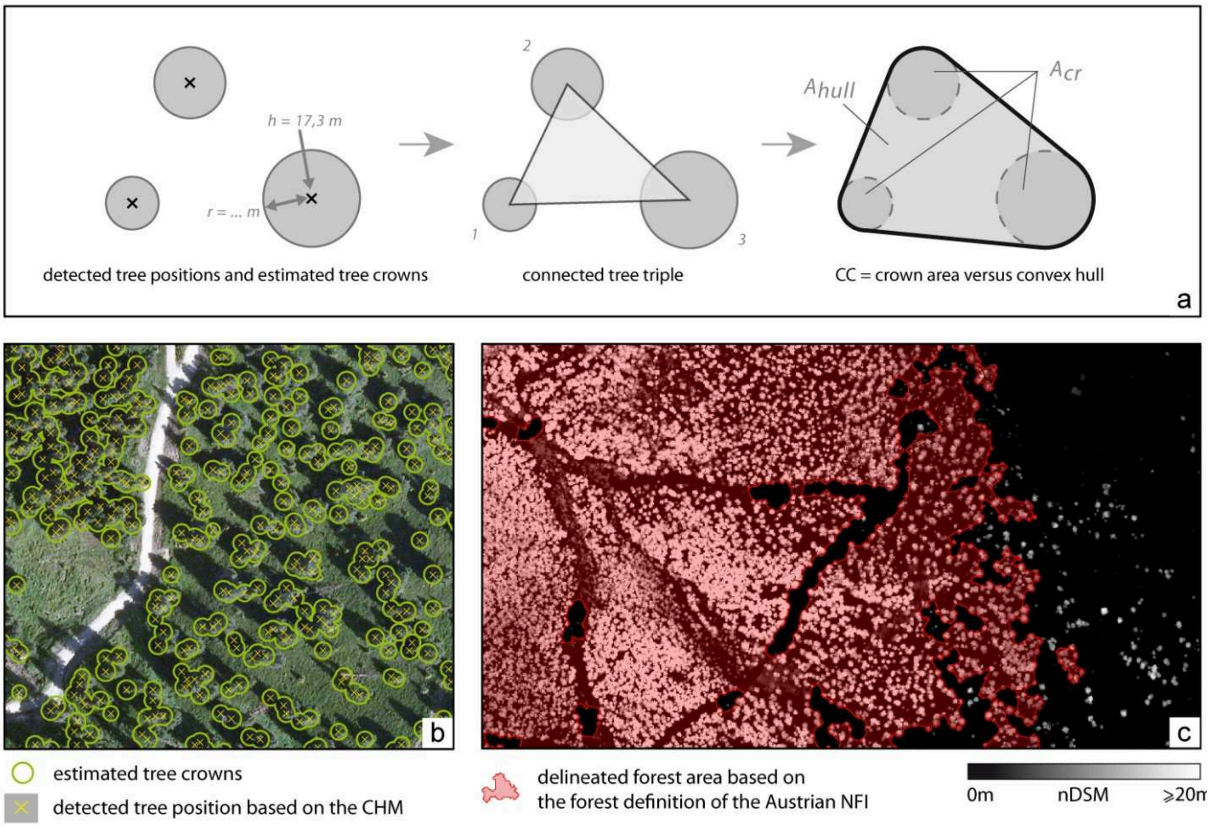

Figure 1: (a) tree triple principle for calculating crown coverage (b) detected tree positions based on the CHM and estimated tree crowns (c) delineated forest area for a loose stocked forest at the upper timberline

References

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