MAP BASED SEGMENTATION OF AIRBORNE LASER SCANNER DATA

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KEY WORDS: Segmentation, Data Fusion, Airborne Laser Scanning, point cloud processing, lidar

ABSTRACT:

The task of segmenting point clouds is to group points that belong to the same (part of an) object. In this project we make use of an existing topographic map as a kind of background layer to segment point clouds acquired by airborne laser scanning systems. This map is an object based representation into polygons which are labelled into topographic classes like buildings, roads, terrain, water and vegetation.

We implemented a point-in-polygon operation which is succeeded by a relabeling step at locations of roof overhangs. Next, the topographic class of the object is used to correctly process the point cloud into meaningful segments. The type of segmentation, e.g. planar or smooth segmentation or connect component analysis, depends on the corresponding topographic class of the object. The segmentation step is extended with a classification step where points are labelled as actually belonging to the corresponding map class or not. This is helpful when dealing with point clouds of cars on roads, or powerlines above the terrain. We segment for example the points on the individual cars into one segment each, but we label those points as not belonging to the class 'road'. This is useful information to filter points from the point cloud when used to generate a 3D landscape model. The result of the map based segmentation algorithm is a point cloud enriched with information on the corresponding topographic class, corresponding map object, a segment number, and an indication whether this point actually belongs the map class or not.

Results on two national datasets show that the use of map information is beneficial compared to a standard segmentation approach. Improvements are shown at situations where in one class a smooth segmentation is more suitable, whereas in the other class a planar segmentation is better, which can only be achieved if the class is known before the segmentation.

1. INTRODUCTION

Lidar is probably the most important technology introduced in the mainstream topographic mapping in the last decades (Shan and Toth, 2008). As the data collected by Lidar is a set of unstructured point clouds, it does not directly show objects, so a series of processes is needed for the point clouds to extract the information. An important step in using Lidar for mapping is segmentation of the point cloud. Segmentation is a process to label segment ID for laser points, so the points which belong to a surface or object are given the same segment ID. The problem is that many segmentation algorithms are fixed in terms of ways of grouping points together. Planar segmentations are very useful when dealing with planar surfaces such as roof planes (Vosselman, 1999; Verma et al 2006; Dorninger and Pfeifer (2008) and Xiong et al (2014), but fail when the scene contain curved shapes.

The main problem is that for a good segmentation, it is needed to know which class the object belong to. For a correct classification of a point cloud however, we need to have some context information to see which groups belong to a certain object. To overcome this chicken-and-egg problem we make use of a large scale topographic map to have an initial guess about the class of the object.

The topographic map gives clear hints on what to expect in the point cloud and how to segment those points into meaningful pieces. For example, if the map indicates that there is a building in a certain area, it is logical to find planar segments in the point cloud. First task is to correctly match point clouds with the corresponding map object, which is challenging not only because of potential small registration errors but also because of differences in object appearances. For example a building in a map may represent the wall outlines whereas the point clouds captures the complete roof, including a roof overhang.

After the fusion process we segment the laser data into logical object wise segments, based on the class knowledge. After the segmentation, it is possible to indicate which points are likely belonging to that class and which do not. At the end of the process the point cloud is enriched by four point attributes, namely the polygonID, the classID, segmentation number and an attribute which indicates the likeliness that this point actually belongs to the class.

The objective of this paper, which is based on the MSc research from Wang (2016), is to present an accurate segmentation model for ALS point clouds of multiple-land-cover landscapes, with the help of maps. Next, the goal is to indicate which segments within each polygon actually belong to corresponding map class. This is helpful for map updating purposes as this is the first indication that a newly acquired point cloud data set may not fit will to the expected object class from an outdated map. After the explanation of the segmentation rules in section 2, results are shown in section 3 and discussed in the conclusions.

2. METHODOLOGY

2.1 Introduction

The general order of the algorithms is:

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- Filtering of point clouds into ground and non-ground
- Point-in-polygon operation
- Reassignment of points on overhanging roofs and walls
- Per class per object segmentation
- Grouping of all segmentation results

Although the first two processes are not part of the innovation of the approach, we shortly discuss them here to explain the assumptions of how the data appears when starting the map based segmentation.

The Lidar data is assumed to be filtered into ground and non-ground data, e.g. using filtering techniques as designed by Axelsson (1999). Next, the Lidar data is expected to be georeferenced in the same coordinate system as the map with a planimetric accuracy in the order of 10-20 cm. In the datasets we used, the above described assumptions are realistic as these are standard properties of the national height model (AHN) of the Netherlands. A point-in-polygon operation is used to link the points to polygons based on the planimetric positions.

Figure 1 Point clouds filtered into ground (left) and non-ground points (middle). Right: a corresponding map.

We implemented an addition to a normal point-in-polygon operation which corrects for unavoidable small registration errors between map and laser scanner data. Specially points on walls are by definition close to a polygon boundary. A smart assigning procedure is needed to connect walls points to building polygons. So an addition is needed to ensure a correct assignment of laser points on overhanging roofs and walls to the corresponding building polygon.

The procedure is that any non-ground laser point within the vicinity of a building polygon is checked whether it is likely belonging to a building than another class. This is done by calculating its local normal direction for detecting vertical planes, and checking whether its fits to a planar segment, e.g. a roof plane or a wall plane.

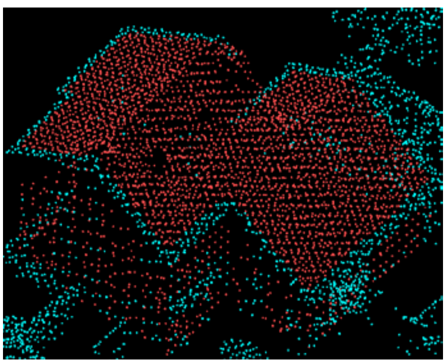

Figure 2 Points within (red) a building polygon. Points of roof overhang and some points on walls (cyan points) are outside the building polygon.

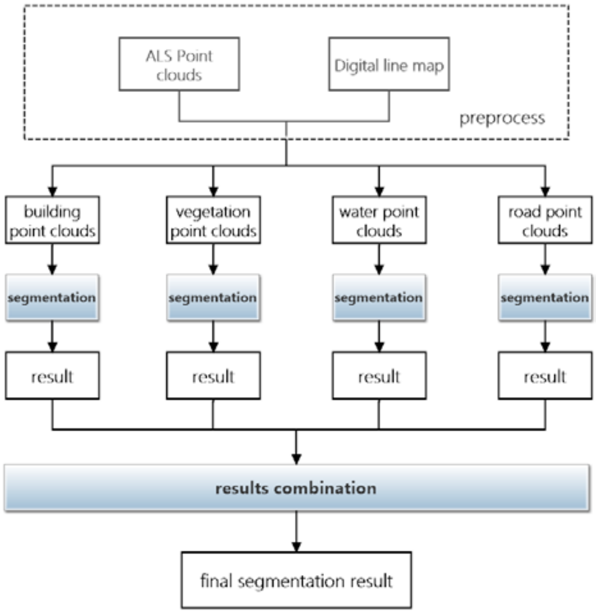

Figure 3 Overall workflow of our map based segmentation approach.

2.2 Point attribute features

To guide the segmentation process, point attributes are calculated to be able to group points based on proximity in combination with constraints on local geometric features. Features like flatness, normal, segment size, max height difference are used in this segmentation model. Flatness is used to differentiate regular manmade surfaces from irregular plant surfaces. Normal of the planes is used to identify wall surface and water surface which are vertical and horizontal respectively. The height difference between the lowest and highest part of a segment is used in re-segmentation of multi-tree components and to differentiate the low vegetation components from tree components.

2.3 Per class segmentation design

After the correct assignment of points to polygons by the adjusted point-in-polygon operation, points within polygons are selected and segmented according to the rules of the corresponding topographic class of that polygon. The rules are explained for the four main classes: buildings, terrain (including vegetated areas), roads and water. The rules are summarized in table 1, and further explained in the following text.

Building	Terrain	Roads	Water
Non-ground points	Ground and non-ground (for trees)	Ground	Ground
Planar segmentation	Connected components per filter type	Smooth surface segmentation	Planar, horizontal
Connected components for smaller details	Individual tree detection		Large growing radius

Table 1 Segmentation rules and processes per map class.

2.3.1 Buildings

Non-ground laser points assigned to building polygons are first segmented into planar segments. The larger planar segments are very likely belonging to the building class. The remaining points are filtered for outliers, followed by a connected component algorithm to group points on larger structures. Structures with many locally planar points, such as dormers and chimneys are considered to be moderate likely to be part of buildings. Other connected components with little planar points, such as vegetation above buildings, will get a label of less likely belonging to buildings.

2.3.2 Terrain

Laser points that fall within polygons with the class terrain contains information on the ground, but also above the ground such as power lines, trees and other vegetation. As such the name “terrain” is confusing but it contains all land cover objects other than buildings, roads and water. Segmentation of the points is done on both types of point clouds: the ground dataset, and the non-ground dataset. For the ground a connected component algorithm is used to group points on the earth surface into large segments. For the non-ground data first the planar segments are found and labelled as unlikely to be part of the terrain class. Next connected component algorithm is used to group points on above ground objects. It is checked whether points belong to linear objects, such as power lines. Multi-tree components are split into smaller segments based on local maxima information, as shown in Figure 4.

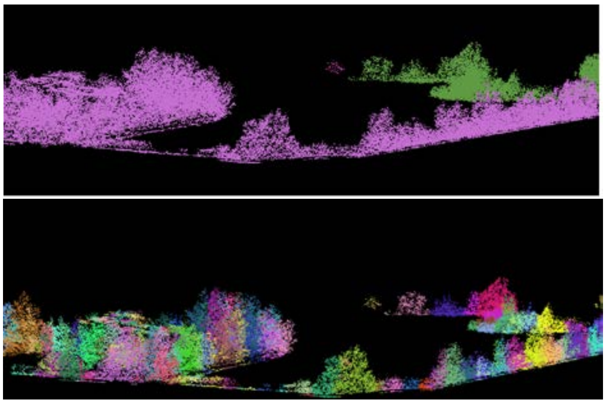

Figure 4 Multi tree components (top) are split into single tree segments.

2.3.3 Roads

Per road polygon ground points are considered to be belonging to the class, in case they fit to large and smooth segments. All non-ground points get a label of not belonging to the road class, and are segmented via a connected component algorithm to group points on objects like cars, and street furniture.

2.3.4 Water

Ground points within water polygons are segmented using a planar segmentation algorithm, where the largest horizontal segment is used as a reference for the main water body. All other horizontal segments at the same height are added to the largest segment in order to bridge possible gaps due to pulse absorption by the water.

3. RESULTS

Results of the map based segmentation are shown and discussed per class. Our algorithms have been tested on area of 1 by 1 km near Den Bosch in The Netherlands. We have made use of two national datasets: point clouds come from the national height model AHN-2, and the map information is from the large scale topographic map BGT. Building points have been segmented in planar segments and small connected components (Figure 5). Points which are within building polygons but unlikely belonging to the class buildings are coloured green in Figure 6x. These are mainly points on vegetation hanging over roof planes.

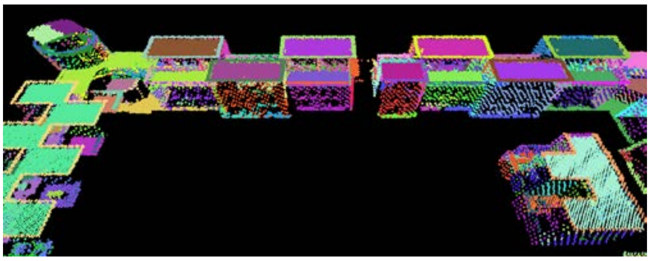

Figure 5 Map based segmentation results on buildings, including points on walls.

Figure 6 Segmented points likely belonging to building class (purple) and not likely (green).

Segmented terrain points from the points in the ‘ground’ dataset are shown in Figure 7. Non-ground points on vegetation and powerlines are shown in Figure 8. Based on linearity measures points on linear objects such as power lines are labelled unlikely belong to the class, as shown in Figure 9.

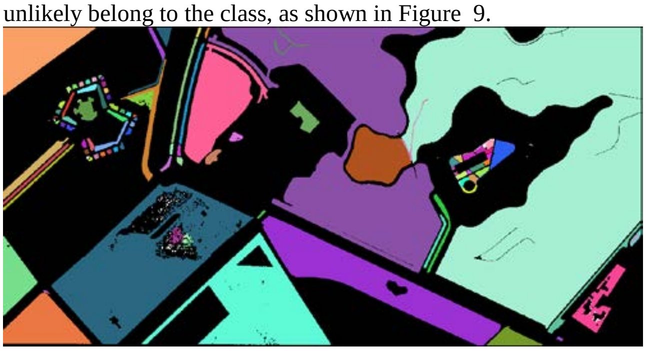

Figure 7 Terrain segments of ground points.

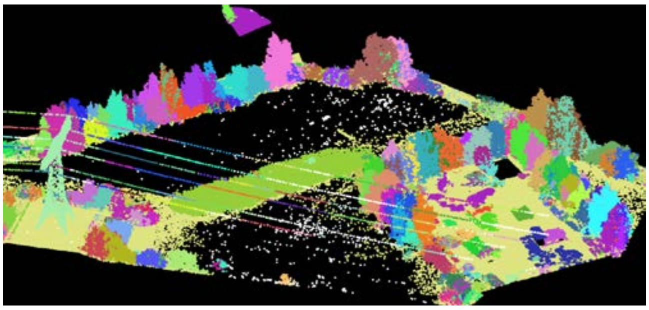

Figure 8 Terrain segments after multi-tree component analysis of non-ground points.

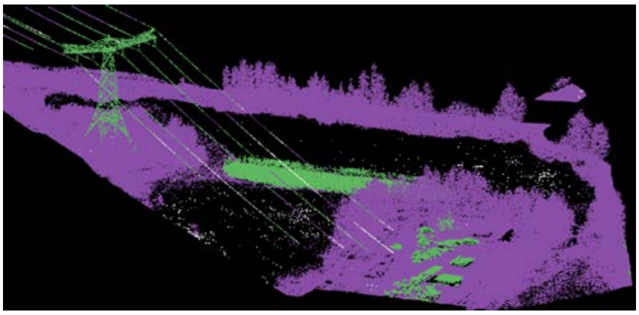

Figure 9 Segmented points likely belonging to terrain class (purple) and not likely (green).

Per road polygon points have been segmented using a smooth segmentation algorithm on the ground points (Figure 10 and Figure 11). A connected component algorithm is applied on the non-ground points to group points on cars, trees and street furniture, see Figure 12.

Figure 10 Ground points segmentation on main infrastructural objects.

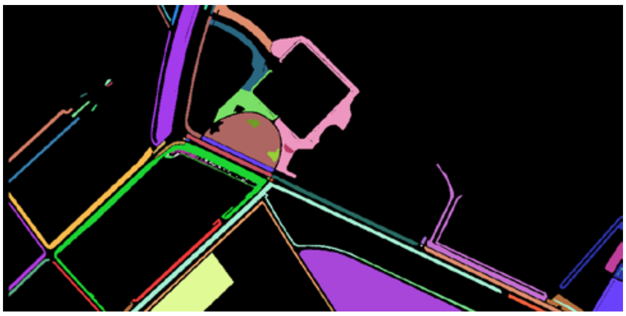

Figure 11 Ground points segmentation on secondary infrastructural objects.

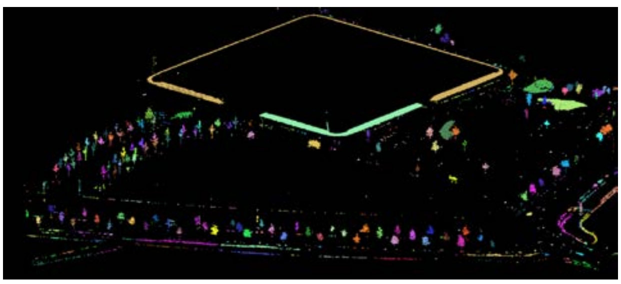

Figure 12 Segmentation on infrastructural objects of non-ground points.

Segments on water surfaces are shown in Figure 13. The area contains a few lakes and many ditches.

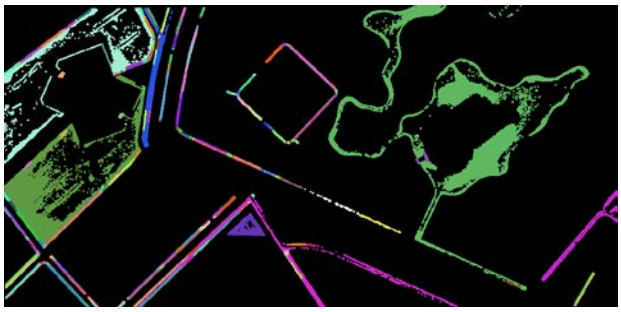

Figure 13 Ground points segmentation of water objects.

All segmentation results are grouped by renumbering of the segment numbers when combining all map based segments. Compared to a normal planar segmentation or connected component approach the map based approach is capable of segmenting both a hilly surface and planar roof faces, see Figure 14. Another reason why the map based segmentation approach appears to be more object based is that it shows boundaries of objects which do not have a height difference, just because there is an object boundary in the map.

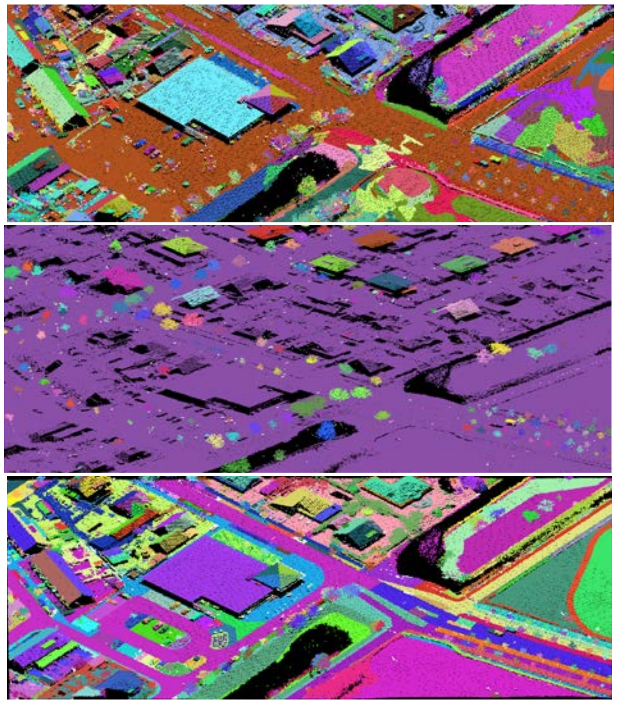

Figure 14 Planar segmentation (top), traditional connected components (middle) and map based segmentation (bottom) results.

At this stage there has not been a quantitative accuracy assessment on the correctness of the segmentation due to absence of reliable and independent ground truth data. In the future we aim to conduct a thorough accuracy check to optimize the segmentation parameters, and to show the potential of this segmentation in 3D modelling and map updating.

4. CONCLUSION

We have presented a segmentation approach for airborne laser scanner point clouds which is adaptive to its corresponding map object and its class. Our approach is able to deal with small registration errors between map and laser data at locations of buildings, as we can reassign wall points and points on

overhang roof faces. At other situations we did not explicitly check whether points actually belong to the neighbouring polygon although we do assign a likelihood that a segment actually belongs to that class.
Our approach ensures a more logical grouping of points towards an object based processing of point clouds. It is shown that by performing a map guided segmentation the point cloud is cleaner in the sense that it is clear which points are useful for further processing. That is beneficial for researchers who use the segmentation result to continue processing for 3D modeling for buildings. They can select the points which are likely belonging to the corresponding map class.

This paper is only the start of using this object based approach in applications. In the future a quantitative accuracy is needed to optimize the segmentation parameters, and to use the cleaned dataset in further mapping steps.

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