Point cloud processing II

Lesson 13*

1 Ground filtering

Ground filtering is a common processing-step for point clouds. It involves classifying the points of a point cloud into ground points and non-ground points. Ground points are those points that are part of the bare-earth surface of the earth, thus excluding vegetation and man-made structures such as buildings and cars. The ground points can then be used to generate a DTM, usually as a TIN or a raster. Or, the non-ground points can be used as input for another classifier, eg to classify buildings and vegetation possibly using a region growing algorithm (see Section 2).

Ground filtering methods are typically based on the assumptions that 1) the ground is a continuous surface without sudden elevation jumps, and 2) for a given 2D neighborhood, the ground points are the ones with the lowest elevation. This is reasonable because non-ground points are typically measurements from objects above the ground such as trees, street furniture and buildings (see eg Figure 1).

Notice that the resulting bare-earth model may thus have holes where these non-ground objects used to be. If needed, these holes can be filled in a subsequent processing step involving spatial interpolation.

1.1 TIN refinement for ground filtering

We will now discuss an effective ground filtering method that is based on the greedy insertion of ground points into a TIN. Indeed, the same algorithmic paradigm of iterative TIN refinement that we saw earlier in Lesson 08 is used. The algorithm consists of three main steps:

1. construction of a rudimentary initial TIN,

(last update: January 8, 2019)

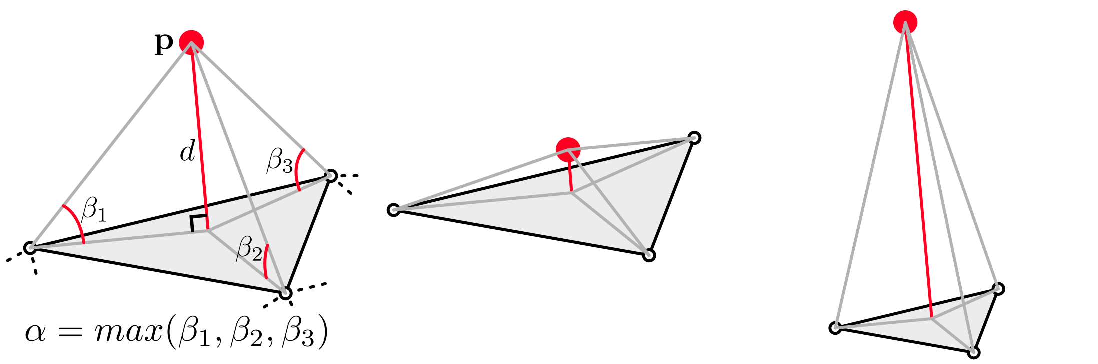
Figure 1: Cross-section of a terrain with lamp posts and trees before (top) and after (bottom) ground filtering (Axelsson, 2000).

2. computation of two geometric properties for each point that is not already labelled as ground, and
3. incremental insertion of points that pass a 'ground test' based on the computed geometric properties.

The latter two steps are repeated until all remaining points fail the ground test.

In the first step a rudimentary initial TIN is constructed from a number of points that have locally the lowest elevation and are spread somewhat evenly over the data extent. These points are found by superimposing a 2D grid over the data extent and by selecting the lowest point for each grid cell (similar to grid thinning). The cell-size of the grid should be chosen such that it is larger than the largest non-ground object (usually a building). Thus, if the largest building has a footprint of 100 x 100m, the cellsize should be a bit larger, eg 110m, so that it is guaranteed that each grid-cell has at least a few ground points. Each point that is inserted into the TIN is considered to be a ground point.

In the second step two geometric properties are computed for each unclassified point. These properties are based on the relation between the point **p** and the triangle in the current TIN that intersects its vertical projection. The two properties are illustrated in Figure 2a. The first



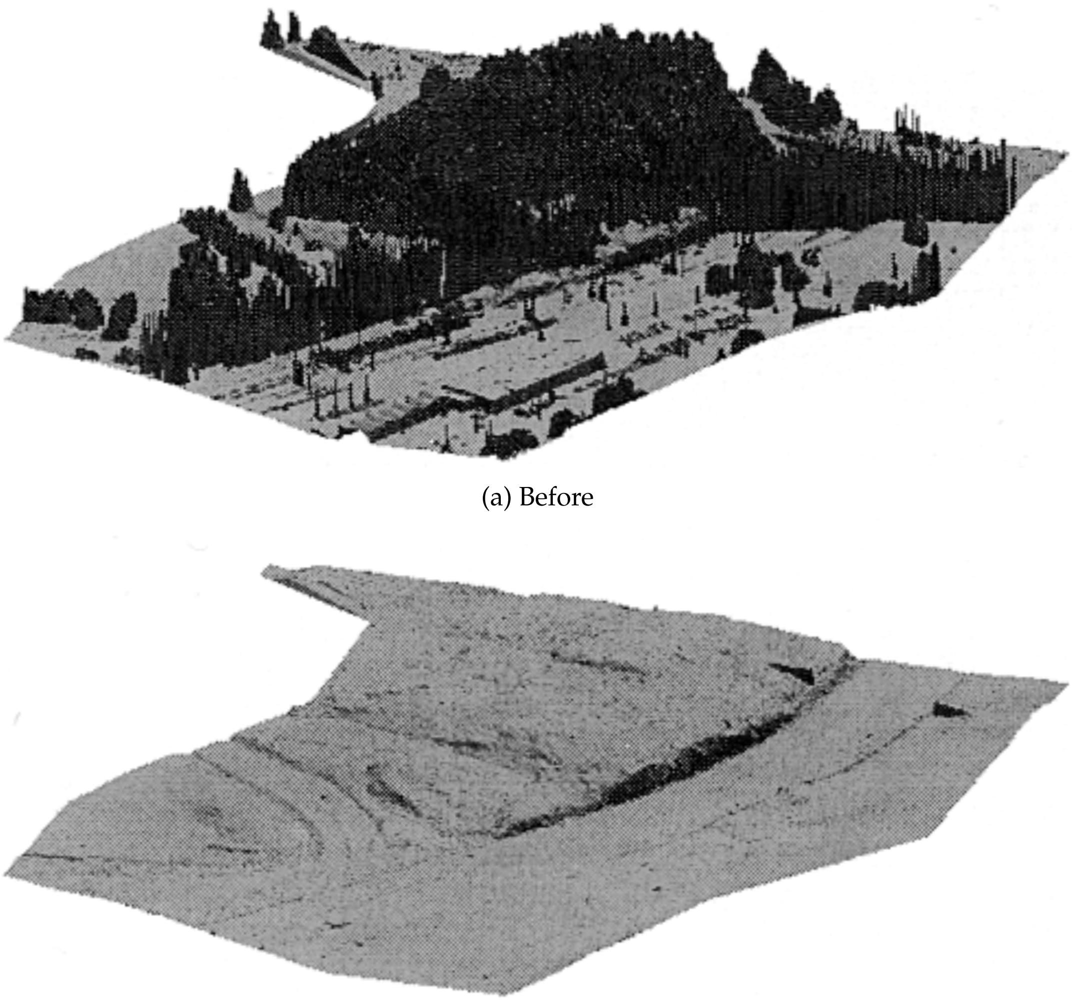
(a) (b) example ground point (c) example non-ground point

Figure 2: Geometric properties for a point **p** in the method for ground filtering based on TIN refinement.

property, denoted d, is the perpendicular distance between the **p** and the triangle. The second property, denoted α, is the largest angle of the angles between the triangle and the three vectors that connect each vertex with **p**.

In the ground test of the final step, it is simply checked for each point if its d is below a given threshold d_{max} and if its α is below a given threshold α_{max}. If this is indeed the case, the point is labelled as a ground point and inserted into the TIN. Compare Figures 2b and 2c.

Of course, if the triangles in the TIN change, the properties of the overlapping unclassified points need to be recomputed. When all remaining points fail the ground test, the algorithm terminates. Figure 3 gives an example result.



(a) Before

(b) After

Figure 3: Ground filtering (Axelsson, 2000)

2 Segmentation

Segmentation is the process of grouping point clouds into multiple homogeneous regions with similar properties. A popular application of segmentation is the detection of planar regions in a point cloud. In this case the point cloud is segmented into groups of points that each correspond to a plane. This can be helpful for something like building classification, if we assume that buildings consist of planar surfaces.

You need to read from the following book. It explains two segmention techniques: RANSAC and region growing. They are explained in respectively

Section 2.3.2 from page 67 up to and including page 69, and
Section 2.3.3 on pages 72-74.

Vosselman G and Maas HG (2010). *Airborne and Terrestrial Laser Scanning*. Whittles Publishing
Online access: `https://tudelft.on.worldcat.org/oclc/843860784`

3 Notes & comments

Axelsson (2000) originally proposed the greedy TIN insertion algorithm for ground filtering. He also describes how to handle discontinuities in the terrain such as cliffs. It should be said that his paper is a bit scarce on details, and if you are interested in those you are better off reading some excerpts of the work of Lin and Zhang (2014).

A comparison with several other ground filtering methods can be found in the work of Meng et al. (2010).

References & further reading

Axelsson P (2000). DEM generation from laser scanner data using adaptive TIN models. *International Archives of Photogrammetry and Remote Sensing*, 33(4):111–117.

Lin X and Zhang J (2014). Segmentation-based filtering of airborne lidar point clouds by progressive densification of terrain segments. *Remote Sensing*, 6(2):1294–1326.

Meng X, Currit N, and Zhao K (2010). Ground filtering algorithms for airborne lidar data: A review of critical issues. *Remote Sensing*, 2(3):833–860.

Vosselman G and Maas HG (2010). *Airborne and Terrestrial Laser Scanning*. Whittles Publishing.