A Contribution to Roof Reconstruction from Airborne Laserscanning

Angelina Novacheva

Institute of Photogrammetry and Remote Sensing, Dresden University of Technology, Germany
angelina.novacheva@mailbox.tu-dresden.de

Abstract. Building models are an important part of contemporary 3D GIS. Airborne laser scanning provides good opportunities for automation of their acquisition. In that the main task is the reconstruction of the roof geometry, as the complete model could then be obtained by projecting its outlines to the surface of a digital terrain model. A strategy for roof reconstruction from airborne laser scanning (LIDAR) data is described in this paper. At first planes within a building region are detected through the Hough transform. Separate segments are then extracted, based on the adjacency relations of a 2.5D Delaunay triangulation. The combined outline of all planar segments constitutes the gutter. A scheme for the reconstruction of brake lines and step edges within the roof structure is presented. Finally, the possibilities of dynamically choosing among different processing options through the implementation of machine learning algorithms are discussed.

1 INTRODUCTION

3D Geo Information Systems have become standard in many planning and decision-making applications. To provide them with accurate and up-to-date data, methods for automated object reconstruction should be developed. 3D building models are of particular interest in areas like photovoltaics, mobile communications, internet GIS etc. Currently their acquisition is based mainly on aerial images, which is time and cost intensive and provides few possibilities for automation. Airborne laser scanning, on the other hand, due to the inherent 3D structure of the data, is much more suitable for automated building reconstruction.

There are two basic approaches to building extraction (H.-G. Maas & G. Vosselman, 1999). The first one is to fit parametric primitives to parts of the point cloud, which provides optimal results for a number of predefined models. The second strategy is more general. It aims at the determination of the roof geometry through the detection of planar faces and their consequent combination. The complete model is then obtained through the intersection of the vertical planes through the gutter edges with the surface of a DTM.

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In the following a procedure for automatic roof reconstruction from airborne laser scanning is presented. It does not operate directly on the Delaunay triangulation of the point cloud, in order to avoid problems with the accuracy of surface normals in dense data sets (F. Rottensteiner et al., 2005), but uses its structure in a number of connectivity tests.

2 ALGORITHM

2.1 Roof Segment Identification

There are two important assumptions related to the proposed algorithm. First the point cloud should have already been segmented in a way that a class of buildings is available. That could be done by pre-processing the data as described in (P. Axelsson, 1999), which does not require additional information like multiple return or intensity values. Secondly the roofs are supposed to be consisting of planar faces.

An overview of the procedure is given in fig. 1. As a preliminary step connected component analysis, starting at randomly selected seed points is responsible for the identification of separate, sufficiently large buildings. The standard deviation (RMS) of plain fit should also be determined a priori and is considered uniform for the data set.

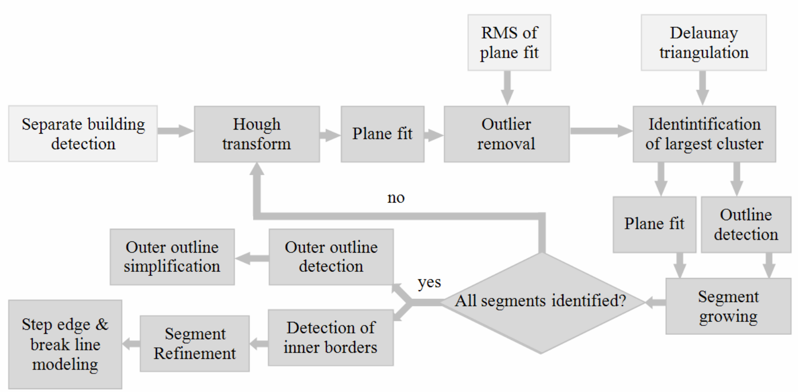


Figure 1: Procedure for building reconstruction.

At first the Delaunay triangulation of a building region is computed. In that, as well as to support further development works, the data structures and the functionality of the Computational Geometry Algorithms Library (CGAL, 2006) are employed.

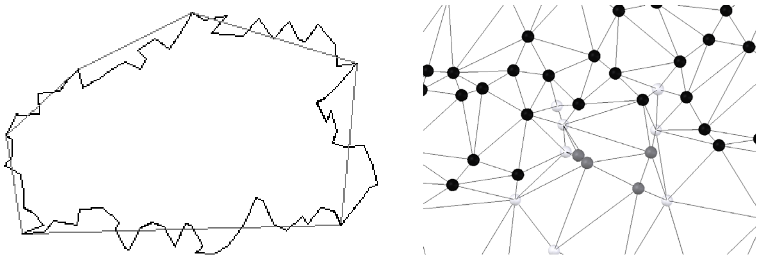
A modified version of the Hough transform is used to detect planar surfaces as described in (A. Novacheva, 2007). Thereafter an improved approximation for the parameters is obtained through adjustment.

Outliers are removed given a predefined threshold for the orthogonal distances of the measurements to the plane based on the standard deviation. Empirically the value of 1.2 x RMS was found appropriate. Given the Delaunay structure, a connected component analysis with double linkage is performed and only the largest cluster is further regarded as a correct detection, with the plane parameters being adjusted to it. That is necessary, not only because of the preceding outlier removal, but also because the Hough transform itself is prone to finding spurious features. The size of the largest connected cluster also serves as a termination criteria for the algorithm – if less than three neighbouring points are left, the roof segment identification is considered completed.

Due to the discrete nature of the Hough space there is no guarantee that all the measurements belonging to one plane will be fully contained within a single accumulator cell. Thus, doubly connected adjacent points to those belonging to the outline of the largest component are also examined against the orthogonal distance criteria applied above, and possibly associated with the plane. In that way the correct spatial extent of the detected segment is obtained.

2.2 Determination of the Building Outlines

To extract the gutter, the 2D outline of the combination of all roof structures is determined (fig. 2(a)). For that a gift wrapping like algorithm has been developed, which uses the neighbourhood information of the triangulation.



(a) (b)

Figure 2: (a) A gutter and its generalization; (b) Delaunay net with detected roof surface (black), non-roof points (white) and roof points omitted due to processing with the double linkage clustering requirement (grey).

Because of the discreteness of the LIDAR measurements, the building footprint will contain many short, insignificant edges and needs to be further generalized. To tackle that problem Ramer's algorithm for polygon simplification has been employed.

2.3 Modelling the Roof Structure

The roof can contain two types of discontinuities - break lines and step edges. Those could be distinguished based on the height differences between the border points, belonging to the corresponding straight line segments of two neighbouring planes. Such distinction is important as each type of feature is modelled in a different way. The position of a break line could accurately be determined as the intersection of a pair of planes. Its length is obtained through the orthogonal projection of the end border points between two segments. Step edges are handled similarly to the gutter.

3 OUTLOOK

One important direction of further research is the integration of machine learning algorithms into the processing pipeline (S. Russell & P. Norvig, 2003). That suggests the identification of problem areas in the procedure and the formulation of different processing options, as well as the definition of attributes with their respective value ranges. Which alternative should be taken for a particular data set or area could be learned through the input of an operator. For example, requiring a single linkage clustering for the roof segments could be suitable when point density is larger than the positional accuracy of the data (fig. 2(b)). However with qualitative data and in urban areas, that could only lead to the unwanted effect of joining separate entities.

The precise position of the ridges could be used for co-registration with image data or for refinement of existing orientation parameters (Schwermann, 1995). Then edges, detected in the images, could be integrated into the procedure to improve the accuracy of the building outline.

4 Conclusions

A method for roof reconstruction from LIDAR data has been presented. It requires a total of four thresholds – two for the angular and distance resolution of the Hough space, one for the removal of outliers and one for the simplification of the building outline. So far the algorithm has only been tested on a couple of separate buildings, which have proved to be hard to reconstruct with other existing automated procedures. The results obtained are quite promissing, however, tests with larger datasets should be conducted to obtain comparable statistical estimation of its performance. There are two main directions in which refinement of the strategy could be sought – the integration of aerial images, including a final adjustment step with all available data, preceeded by variance components estimation (Koch, 2004), and the incorporation of machine learning algorithms.

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