FUSION OF LIDAR DATA AND ORTHOIMAGE FOR AUTOMATIC BUILDING RECONSTRUCTION

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1. INTRODUCTION

Recent years LiDAR (Light Detection and Ranging) data is widely used for constructing 3D terrain models which provide realistic impressions of the urban environment. This paper presents an automatic method for extracting 3D building model by the fusion of LiDAR data, 2D building outlines and orthoimage. 2D building outlines is generated by classifying the LiDAR data to terrain and off-terrain points, then detecting building edges points through step-structure detector and generalization. 2D building boundaries are added on the DSM (digital surface model) from LiDAR data to generate complex buildings by used CSG with the Boolean operations of union, intersection and differences [1,2].

2. DETECTING BUILDING OUTLINES

As shown in Figure 1, the left side is process of extraction 2D building outlines from raw LiDAR data, then the 2D building outlines is taken as input data in the reconstruction procedure as shown in the right side. Processing starts by decomposing the building outlines polygon into 2D primitives. Each 2D primitive including location, orientation and size is the corresponding 3D primitive. Then determine height of the building, roof type and slope. With the given DSM estimate the best fit models [1]. The focus lies on detecting building outlines and taking the characteristics of buildings into account to produce a meaningful 2D building outlines.

2.1. Point clouds Classification

The airborne laser scanning technology is able to capture very dense 3D point clouds from the terrain therefore 3D building reconstruction from LiDAR becomes feasible. At first all point clouds data should be classified into terrain and off-terrain points. The methods of Kraus & Pfeifer [3] and Abo Akel et al.[4] are commonly involved before the laser scanning data was used for 3D model reconstruction.. The latter one is used in this paper, but we changed areal polynomial to a set of 1D-polynomials so the 2D classification was simplified to 1D which makes the classification fast.

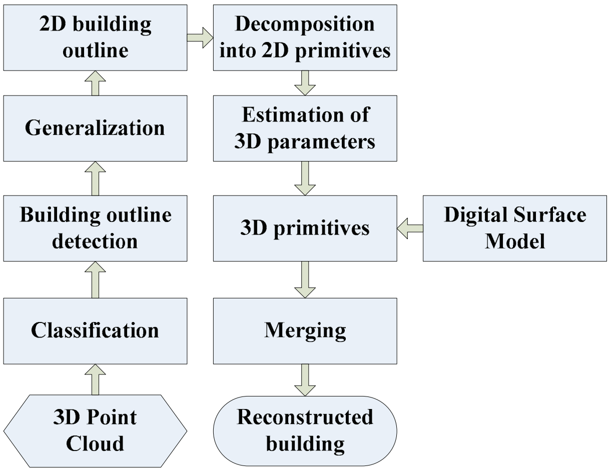


Figure 1. Workflow of automatic reconstruction building models.

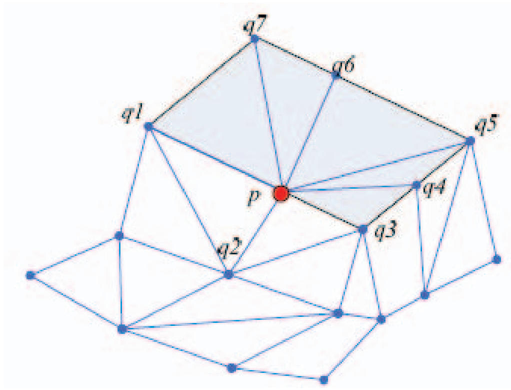


Figure 2. Determine edge points

2.2. 2D Building outlines Detection

Secondly, different building detection algorithms are involved to extract the 2D building outlines from the laser scanning data. Some researchers interpolated points to regular grid[5], these methods are easier because they translate boundary tracing of discrete point clouds to edge detection of images and used image edge detection operator to detect a straight line features including Laplacian, LOG, Prewitt, Roberts, Sobel, SUSAN and Canny, but the results of edge detection may deteriorate and accuracy goes down during the process of points interpolation.

In this paper, step-structure detector is used to avoid above problems. The building edge points should be on a higher elevation step position. A series of points that format the edge should have steep slope and consecutive points have rapid change of height. So the determine edge point approach is finding height differences of each point and its neighborhood point.

Suppose point p is adjacent to number of n points $q = \{q_i | q_1, q_2 ... q_n\}$ and its coordinates on z axis is p_z, q_{iz} is the coordinates on z axis of q_i. Z coordinate difference from q_i to p is $d_i = q_{iz} - p_z$; Set $d_{\max} = \max(d_i)$ is the largest one of all d_i while $d_{\min} = \min(d_i)$ is the smallest one, if p is satisfied with the following two conditions: (1) $|d_{\min}| > |d_{\max}|$ (2) $d_{\max} - d_{\min} > T_h$; then p is the step edge point. Where T_h is a given threshold, if the height difference of the surrounding points of p is greater than T_h, then p is a possible step edge point.

As the example shown in Figure 2, there are eight points including p and seven adjacent points $q_1, q_2 ... q_7$. Suppose p, $q_1, q_2 ... q_7$ have the same height, then $d_{\max} = 0$, $d_{\min} = q_{2z} - p_z < 0$. Based on the above two conditions, if the $d_{\max} - d_{\min} > T_h$ then p is a step edge point. Accordingly a careful study adjacent points of q_2, it is obviously not satisfied with conditions one, so only p can be selected as the step edge of the actual edge point.

After acquisition all these discrete step edge points, a method combine RANSAC (Random Sampling Consensus)[6] with Least Squares Adjustment[7] is used to connect points to straight lines. Figure 3 shows some results for the detection of building outlines: left side is the building orthoimage; in the middle, the outlines generated by step-structure detector are shown; whereas on the right side, the straight lines generated by the randomly chosen start and endpoints of a line are given. It is clearly visible that there are many broken line segment and still need adjusting outlines to produce a meaningful 2D building outlines.

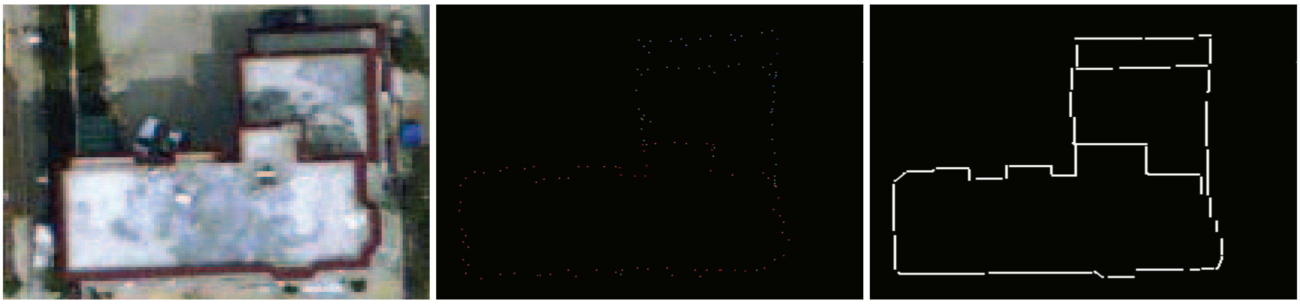


Figure3 orthoimage (left); outline points detected by step-structure detector (middle); building straight outline (right)

2.3. Generalization

There are many broken line segments which originally belongs to one edge line, so firstly connect these pieces for a longer segment. If the segments are satisfied with the two conditions: 1) the angle between the two line segments is relatively small, and 2) the distance between the two line segments is less than a certain threshold, then the two line segments can be merged.

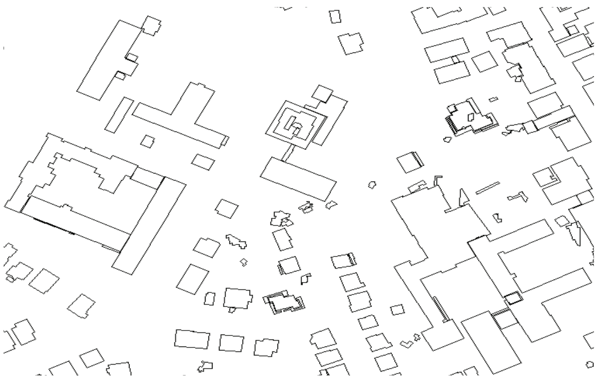
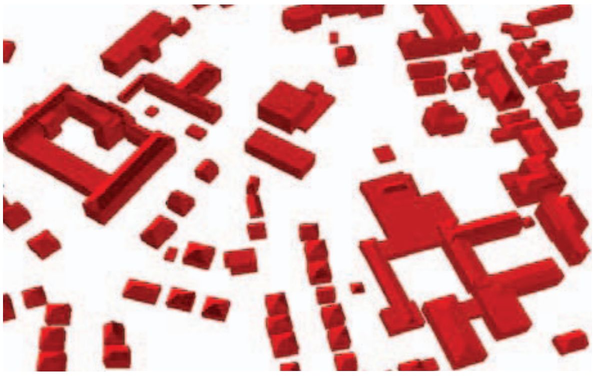


Figure 4. 2D building outline results

Buildings are man-made objects and mainly consist of straight lines that are linked using additional constraints concerning rectangularity and parallelism. Therefore those straight lines should be adjusted to the original building outline using additional constraints that take the building characteristics into account. In this paper we use a simple method to calculate parallel line segment. The angle between each straight line segment and X-axis should be calculated, if the angles of the number of straight line segments are similar, these line segments are seem as parallel. Then all these line segments are parallelized together. The length of the segment can be used as a weight to control segments change, for example, the segment is longer the change of it is less. The same adjustments are done for the vertical line segment. The parallel and vertical adjustments need to be repeated several times until no suitable segment can be found. Figure 4 shows the 2D building outline which was extracted from an area with above methods.

3. AUTOMATIC RECONSTRUCTION

In this paper, we use the automatic method of Brenner[1] , which transformed the problem of reconstructing complex buildings into reconstructing its basic units (primitives) . The right side of Figure 1 sketches the workflow of the reconstruction algorithm. As shown in Figure 5, the building models are completely extracted with mapping texture by fusion of orthoimage.



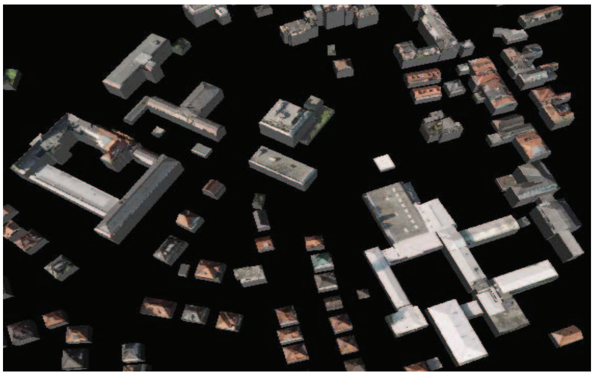


Figure 5. Automatic reconstruction results(left) Automatic reconstruction results with texture mapping(right)

4. CONCLUSIONS

This paper shows the steps and methods for using laser scanning data and orthoimage to generate 3D building model automatically. The step-structure detector allows us to find the building boundaries in laser scanning point clouds and generate straight outlines with RANSAC and Least Squares Adjustment. Additional man-made building constraints characterize the outlines to preserves the topological connectivity so as to 3D building models can be automatically reconstructed by fusion of those building outlines, LIDAR data and orthoimage. The following research will focus on adding more constrains, so boundary will be more reliable.

5. REFERENCES

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