AUTOMATED EXTRACTION OF BUILDING GEOMETRIC FEATURES FROM RAW LIDAR DATA

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ABSTRACT

In recent years, with new services expected, such as navigation systems, location based services, and augmented reality, the need for automatically, efficient 3D building reconstruction systems becomes more urgent than ever. As a new spatial information technology, airborne LiDAR is widely used for the acquisition of 3D objects on the earth. The automatic reconstruction of 3D buildings from airborne LiDAR data has been a topic of research for decades. However the lack of 3D building reconstruction methods is still the bottleneck for the further development of airborne LiDAR. Since the 3D geometry feature is extremely important for many applications such as urban planning, car navigation, or environment monitoring etc., this paper introduces an automated method for implementing building geometric features extraction from raw LiDAR data in details. The outlines of 3D buildings are generated by using discrete curvature analysis according to the building geometry features. In the experiment, 3D building models are automatically reconstructed by using a model-driven approach according to their geometry features derived from raw LiDAR data.

Index Terms—Airborne LiDAR, geometric feature, 3D building models reconstruction

1. INTRODUCTION

Up to now LiDAR (Light Detection And Ranging) sensors and data has been widely used from the domain of research and development into the general marketplace primarily as a means of rapidly generating dense, accurate, digital models of the topography and vertical structure of a target surface. LiDAR sensors are usually employed for mass production of high accuracy digital elevation models (DEMs), digital terrain models (DTMs) and triangulated irregular networks (TINs). LiDAR elevation data is ideally suited for mapping extensive areas where very high accuracy elevation data is required rapidly, especially in urban regions [1-2]. 3D building information is extremely important for many applications such as urban planning, car navigation, or environment monitoring etc. In this paper, we define an efficient geometric feature descriptor based on the theory of discrete differential geometry and present an automatic approach for extracting building geometric features from airborne LiDAR data.

2. RELATED WORKS

The building geometry features extraction from high-resolution urban LiDAR data is of primary importance in many applications, including urban planning, telecommunication network planning and vehicle navigation which are of increasing importance in urban areas [3]. The extraction of building geometry features is of great importance in the earth science field, for example the earthquake damage assessment, the difference geometry features derived from pre- and post-earthquake LiDAR data revealed successfully the collapsed buildings, caused by the earthquake [4-6]. The critical element of detecting earthquake-induced heights changes through the DSM differencing method, was deciding where to place the boundaries between change and no-change pixels. Thus, if a building geometry features were detected from the pre-earthquake and post-earthquake LiDAR then the feature differences caused by earthquake could be omitted.

Nowadays various methods for detection and reconstruction of building models from laser altimeter data are applied to the irregularly spaced point cloud (as shown in Figure 1). Some methods directly derive the surface parameters in a parameter space by clustering the point cloud [7] while the others segment a point cloud based on criteria like proximity of points or similarity of locally estimated surfaces [8]. Some approaches focus on finding the region of interest and incorporates simple rules to extract the building models with different roof types [9], execution of region growing algorithms based on least squares adjustment of point cloudy [10], generation of building wireframes model from the LiDAR data [11]. Kokkas and

Dowman (2006) presented a semi-automated method for reconstructing the building models by fusing LiDAR data with stereo matched points extracted from the airborne photograph stereo model [12]. In their method, the roof reconstruction is achieved by implementing a least squares-plane fitting algorithm on the laser data. The subsequently neighbouring planes are merged using Boolean operations for the generation of building geometry features. Recent approaches developed segmentation methods of LiDAR point clouds without any external data [13].

In contrast to most of the previous work, the goal of our approach is the accurate geometric description of the surface independent of the respective building type. Thus, our method relies on a generic description of building characteristics on the basis of the discrete differential geometry principles rather than on specific and explicit building models. The proposed approach for extracting building geometric features consists of three processes: generating Digital Surface Model (DSM), describing geometric features, and extracting building features. Finally, the paper concludes with an outlook on further research work.

3. GENERATING DIGITAL SURFACE MODEL

The techniques presented in this paper were applied to a Leica ALSII laser altimetry dataset (as shown in Figure 1). Firstly, as shown in Figure 2, DSM is generated from these raw LiDAR data. This processing step generates a TIN surface of high quality based on the raw LiDAR point clouds. During the triangulation, a 2D-Delaunay Triangulation is applied, which is a common procedure to approximate a real surface that is irregularly sampled by points.

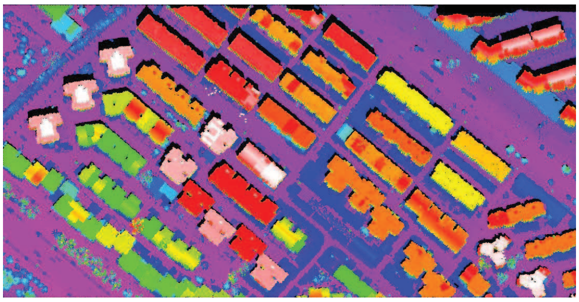


Figure 1. Raw LiDAR point clouds.

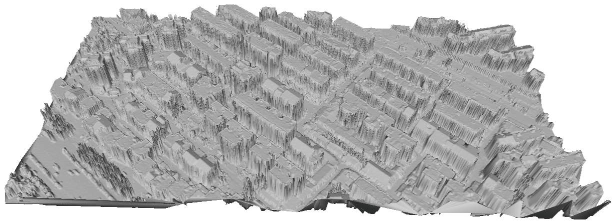


Figure 2. DSM from raw LiDAR data.

4. DESCRIBING GEOMETRIC FEATURES

Multi-spectral imagery may be useful to distinguish feature vertices from zero-feature vertices according to their difference in gray gradient. However, in this paper, based on the theory of discrete differential geometry [14-15], an efficient geometric feature descriptor was defined, to separate vertices according to their geometric shape characteristics because ridges, valleys and flat planes have significantly difference in their geometric shapes. Differential geometry is geometry done using differential calculus, in other words, shape description through derivatives. The underlying equation was employed as the geometric feature descriptor of vertices to indicate whether they are feature vertices or zero-feature vertices.

$$F(v_i) = \beta_{\max} \| e_{i,\max} \| \tag{1}$$

where n is the number of adjacent triangles to v_i, $\beta_{\max}$ is the max dihedral angle between each two triangles that adjacent to vertex v_i, and $\| e_{i,\max} \|$ is the corresponding length of edge $e_{i,\max}$ (as illuminated in Figure 3). This means that the vertex, which has bigger dihedral angle between adjacent triangles and longer distance from adjacent vertices, is to be regarded as a salient feature point.

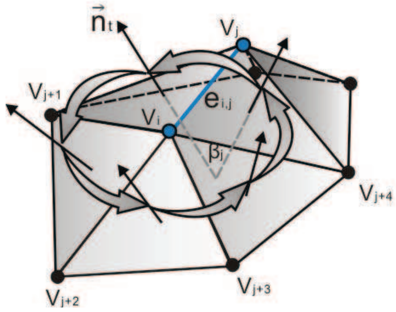


Figure 3 Calculation of geometric feature descriptor.

Let the geometric feature map F (as illuminated in Figure 4) define a mapping from each vertex of a DSM (as illuminated in Figure 2) to its geometric feature, i.e. let $F(v_i)$ denote the feature of vertex v_i .Figure 4 shows the result of detection of geometric features, such as ridge, valley and boundary features using the geometric feature descriptor. We use pseudo-colors to show the geometric features according to the value of geometric feature descriptor: warmer colors (reds and yellows) show salient features, cooler colors (greens) show general features, and blues show zero-feature. Then the feature points were linked to generate closed contour lines on building surface. In next procedure, the region growing segmentation was guided by using this normalized feature map F.

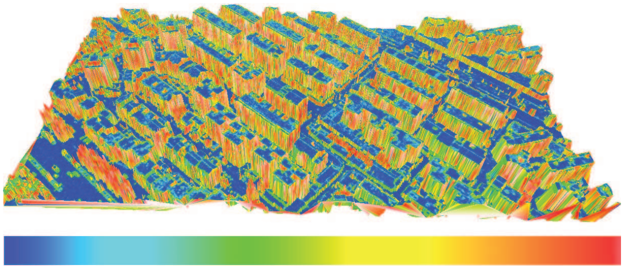
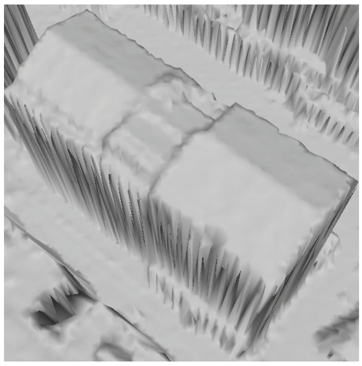


Figure 4. Pseudo-colors showing the features according to the geometric feature descriptor: warmer colors (reds and yellows) show salient features, cooler colors (greens) show general features, and blues show zero-feature.

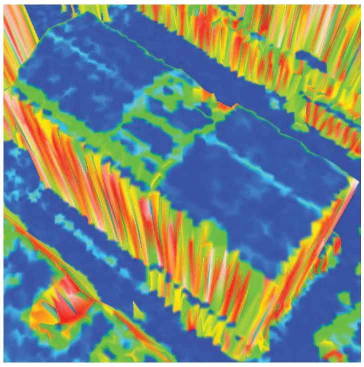
4. EXTRACTING BUILDING FEATURES

This processing step can be summarized as a region growing segmentation algorithm that uses random seeds, geometric constraint (e.g. in this paper, closed contour lines) and growing criteria (according to the value of geometric feature descriptor). The processing of region growing generates the roof segmentations and wall planes, which consist of points with the same classified features, in the scope of closed contour lines. As shown in Figure 5, the experiment shows a very promising result with a good performance in terms of rapid running time.

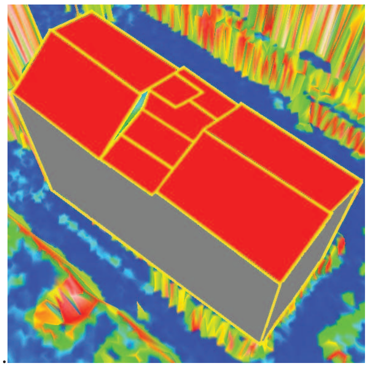
Now the roof outline is determined, so the vertical wall planes can be constructed through all edges of the outline. These wall planes are intersected with the roof faces in order to find the remaining edges of the roof faces and to determine the height of the walls. An example of the edges that result from the intersections of pairs of roof faces and of the roof faces with the adjacent walls is shown in Figure 5(c). All roof face edges are now determined. The complete outline of each roof face is reconstructed by intersecting the edges with nearby end points. Since all edges are in the same plane, there are no misclosures at the intersection point. At points where four or more different planes meet the reconstructed points are averaged to form a common node. Finally, the ground level of the walls was set to the height of the lowest point in the vicinity of the building.



(a) original DSM.



(b) pseudo-colors showing its feature distribution.



(c) results of region growing segmentation

Figure 5. Detecting and extracting geometric features.

After the extraction of building geometry features, the geometrical roof construction is invoked again to yield the final roof. The reconstruction is completed by a least squares adjustment of the roof height and the addition of vertical walls. Figure 6 shows the final reconstruction models of buildings for the initial hypothesis shown in Figure 1. These models are derived from raw LiDAR data according to their geometry features by using a model-driven approach [16], which is a fully automatically method and also supports interactive modeling for complex buildings. The results showed that the proposed approach has really good performance. This approach has great potential for practical use in photogrammetry and remote sensing industry.

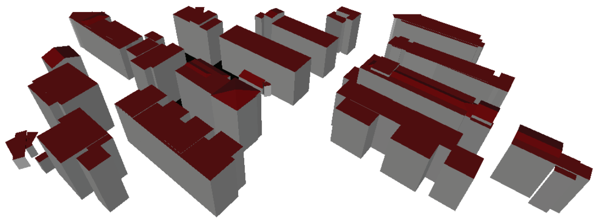


Figure 6 Group of 3D building models derived from raw LiDAR data.

6. CONCLUSION AND OUTLOOK

In this paper, we have presented a method to extract building geometric features from raw LiDAR point clouds automatically. The experiment was performed with raw LiDAR data from the Shashi city, China and we demonstrated good results with respect to human perception. Further studies will be conducted in quantitative evaluation and a comparison with existing methods. Future work should concentrate on the fusion with photogrammetric imagery for a sharper modeling of edges and the fusion with multi-spectral imagery to support the segmentation process. 3D building reconstruction and fusion with high-resolution orthograph images will also be explored in our future work.

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