Simplification of LIDAR Data for Building Extraction Based on Quad-tree Structure

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Abstract

LiDAR data is very large, which contains an amount of redundant information. The information not only takes up a lot of storage space but also brings much inconvenience to the LIDAR data transmission and application. Therefore, a simplified method was proposed for LiDAR data based on quad-tree structure in this paper. The boundary contour lines of the buildings are displayed as building extraction. Experimental results show that the method is efficient for point's simplification according to the rule of mapping.

1. Introduction

Last few years have seen a growing need for geographical information and processing applications. Remote sensing of urban areas provides a quick and efficient way of data acquisition. Data can be acquired through a variety of sensors most of which belong to optical, thermal, hyper-spectral, laser and synthetic aperture radar categories. The sensors are ground-based, aerial or space-borne. LiDAR (Light Detection And Ranging, also LADAR) has become very popular technique for acquiring terrain elevation data. LiDAR Data produce extremely large models of digital terrain, which must be simplified to be useful. Reducing the complexity of irregularly sampled point clouds has been one of the most important problems addressed by the scientific visualization and other communities for well over a decade. Most of the resampling/ simplification literature has been focused on point sampled smooth manifold surfaces. Because of relatively recent availability and relatively lower sampling density of LiDAR data the problem of resampling/ simplification has not received similar attention.

In cartography, methods for the simplification or generalization of building ground plans have been developed [1]. All try to eliminate too small edges, protrusions and insets of the buildings, while preserving and enhancing the properties of buildings like right angles or parallelism. These methods, however, cannot be directly transferred to the problem of simplifying outlines determined by laser scanner data analysis, as those outlines are only coarse approximations of the real building; they are typically jagged and potentially also spoiled with outliers [2].

In the next section, the related theory is introduced. The following section explains the detailed approach to extract building outlines is described. Then the experimental results are presented. Finally, a conclusion is described.

2. Quad-tree Structure

This structure has been implemented within the Gerris Flow Solver framework [3]. Gerris was initially designed to solve the incompressible Euler equations with complex boundaries [3] but has since been extended to the linearised shallow-water equations [4], multiphase incompressible Navier-Stokes equations [5], and spectral wave models [6] as well as coupled problems including electro hydrodynamics [7]. Gerris uses a quad-tree (octree in 3D) spatial discretization which allows efficient adaptive mesh refinement. An example of the quad-tree structure is represented in Figure 1 together with its logical (tree) representation. This tree can be conveniently described as a "family tree" where each parent cell can have zero or four children cells.

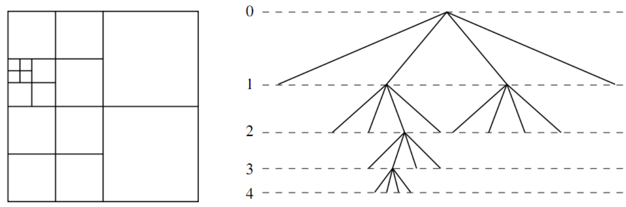


Figure 1. An example of quad-tree structure (left) together with its logical representation (right).The level of the cells in the tree is also given.

An important parameter is the level of a given cell in the tree. The root cell has level zero by convention and the level increases by one for each successive generation in the tree. Details of the actual implementation in Gerris can be found in [3]. A further simplification is obtained by constraining the quad-tree so that the level of adjacent cells cannot differ by more than one. This reduces the number of configurations for neighboring cells to two: 1) neighboring cells are on the same level. 2) Two fine cells are neighboring the same coarse cell.

3. Method

A major issue as a basis for managing and processing task is to clearly define inputs and outputs. For LIDAR data, the specification of the input file format is therefore a crucial task and has been first tackled in this paper. We used an ASC file as input data, and files with an extension of ".ASC" are usually ASCII text files, similar to the TXT file format. In our LIDAR data, it is represented by an (x, y, z, i) quaternion with x and y denoting coordinates, besides, z and i denoting a height and intensity measurement at that location.

By using quad-tree, we can transform LIDAR data from irregular data to regular data. As we know, LIDAR data are in the dense pattern. It is necessary to reduce the size of quad-tree first before processing data. Based on the quad-tree structure, we proposed a method to reduce the size with keeping accuracy. The detailed description as follows:

Just like the quad-tree structure, a quad-tree with a threshold allows us to reduce the size of the tree at the cost of prediction accuracy, as it is no longer an exact copy of the original data. Furthermore, setting the accurate threshold value of height was set to simplify a quad-tree. A threshold means a criterion to merge any adjacent nodes as a single node. If the height difference for the adjacent nodes is smaller than the predefined threshold.

Though each sub-quad-tree following threshold merge, this method is still incapable of being defended or justified if this is practicable or feasible. To prove our viewpoint, we make a simple experiment to extract the boundary of buildings.

After reducing the quad-tree, we can generate the regular data, and then classify these data and find which part of these data belongs to building or noise points (ground and mountain). Next step, we will remove these ground data points, and give a threshold with height to check the x and y value of each point. In order to take off the mountain points, we used a slope to make sure the leaving points are all building points. In this way, we can make different groups of these data with different height value. For each group, running the Andrew's Monotone chain algorithm to find out the boundary points, that means each group of boundary points denote one object. Finally, we can store these boundary points to draw the picture.

4. Experiment and Results

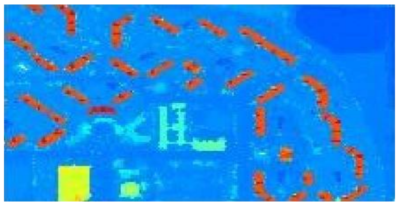
In the first of all, we open and read a LiDAR data file which is ASC file format. The first and second columns denote the coordination of x, y; the third column denotes z as height value, and the last column denotes the intensity value. Each row denotes one data. And then we build a quad-tree structure. Threshold will be decided to reduce the size of quad-tree before transforming irregular data into regular data. In this experiment we get the reduced number of nodes in the quad-tree structure by setting different threshold.

After simplifying the LiDAR data, there are some interference factor, ground and mountain, existed in the dataset. In order to remove these noise points and get building shape, the method can be describes as followings:

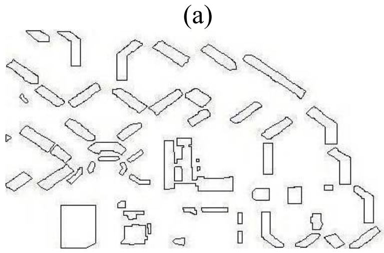
1. To discern the result of this experiment clearly, we pick up a part of the original image as a sample image, shown Figure 2(a).
2. Taking off the ground and mountain to combine the slope with adjusted height value. In this paper, we allow to save the point which height value is more than 45, and the slope is 3.0.
3. Classifying these points to different group by checking their height value and distance for every two points. I give a distance value which is 5.0m.
4. Making each shape for different groups by using Andrew's Monotone chain algorithm, and then painting the lines for them, shown Figure 2(b).

5. Conclusion

In this paper, the proposed method started with building a quad-tree and simplifying this structure. Then we divided these data into two parts of ground and building. For the each building group, we generated the contour line by using Andrew's Monotone chain algorithm. Through making an experiment, we analyzed that how to simplify data under the premise that guaranteeing the accuracy of LiDAR data, and get the basic shape for each building.



(a)



(b)

Figure 2. (a). The sample image (b). The building extra ction of the sample image

This paper do not only focuses on the accuracy of boundary points. However, with adjusting threshold or applying more sophisticated object extraction algorithms will generate more precise objects. During the experiment, it proved our algorithm can simplify some pre-processing works well for a large number of data set and guarantee the accuracy of building shape. Therefore, it is suitable for LiDAR data of object extraction application.

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