Building Extraction from LIDAR Based Semantic Analysis

YU Jie YANG Haiquan TAN Ming ZHANG Guoning

ABSTRACT Extraction of buildings from LIDAR data has been an active research field in recent years. A scheme for building detection and reconstruction from LIDAR data is presented with an object-oriented method which is based on the buildings' semantic rules. Two key steps are discussed: how to group the discrete LIDAR points into single objects and how to establish the buildings' semantic rules. In the end, the buildings are reconstructed in 3D form and three common parametric building models (flat, gabled, hipped) are implemented.

KEYWORDS LIDAR; building extraction; semantic rule; object-oriented method

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Introduction

Thanks to a large number of applications, such as map updating, urban planning or land use analysis, extraction of artificial objects, such as buildings, roads from the images has been an active research field for many years. Since buildings are the dominant objects in urban areas, the discussion in this paper focuses on building extraction.

The traditional manually building extraction from raw imagery is highly labor-intensive, time-consuming and very expensive, so the strong demand for the ground information led to increasing efforts in developing new hardware and software to minimize the costs, and the research is going towards an automated method.

In recent years, active sensors, which can measures 3D topography directly, have been developed. LIDAR (light detection and ranging) has become an accurate, cost-effective alternative to acquire the ground information at very high accuracy. This technique directly acquire the signal with x, y, z and intensity of the target on the earth’s surface. These point clouds provide the 3D information of targets, and the intensity information can reflect the properties of the ground objects such as material, texture, etc.

Several methods have been developed to detect and reconstruct the building model from LIDAR data, e.g., Brenner uses interpolated DSM (digital surface model) from LIDAR data and 2D ground planes as data sources for an automatic and/or semiautomatic reconstruction process[1], Vosselman and Dijkman use 3D Hough transform to extract the planar faces from the irregularly distributed point cloud[2], Wenbo Song, et al use the building’s geometric characteristics such as size, height and shape to separate buildings from other objects (tree, etc.)[3]. Martin Huber et al mix LIDAR data and aerial photos together to reconstruction the buildings[4].

In this paper, a scheme is presented to extract and reconstruct buildings solely based on LIDAR data. It is an object-oriented method that is based on the buildings’ semantic rules. Because
of the discrete and irregular distribution of the LIDAR points, the information we can get from these single points is limited, especially, the semantic information about the objects on the earth can not be represented by the individual points. Therefore, in this paper, the buildings are extracted on the basis of semantic analysis idea. This proposed scheme consists of two steps. First we extract the meaningful points blocks using a region growing technique to generate the single ground object. Next we can analyze the buildings' semantic rules in the aid of aerial images, and use these rules to determine whether the points block belongs to a building. At last, the buildings can be reconstructed in 3D form after all the buildings have been detected in our test area.

1 Generate ground objects from LIDAR point clouds

1.1 Filter LIDAR data

Before the extraction, a LIDAR data preprocess is needed, namely filtering, which can divide the LIDAR data set into ground points and non-ground points. The non-ground points are all the points on the surface of ground objects, including vegetation, building roofs, vehicles and other natural or man-made objects. Building extraction is based on the non-ground points, which are obtained after filtering. There are some available algorithms for the LIDAR data filtering, such as ETEW, PM, MLS, Motion curved surface fitting etc. Fig. 1 (a) shows the 3D form of the LIDAR point clouds before any processing, and Fig. 1 (b) shows the LIDAR point clouds after filtering. It is obvious that the data set only includes the points of the ground objects after the filtering processing.

1.2 Generate object

Different from the classification and extraction of feature based on LIDAR data points singly, which are used usually, in this paper, the buildings are extracted by an object-oriented method in which the targets are to be analyzed as objects.

The single ground object can be generated by grouping neighboring LIDAR points into an object area. The ground points and non-ground points have been separated after the filtering, and the grouping is based on the non-ground points. To generate single object, we can group adjacent points by means of region growing technique. This approach is based on the concept that the adjacent points always belong to one ground object. A random point is selected as seed point, and to seek adjacent points around the seed point in certain distance, then to shape one region. The growing does not stop until meeting a specified threshold, which is the distance between the new point and the shaped region, and the shaped region can be considered as a single object. Then another point is selected as seed point to continue growing to shape another region. All the ground objects are generated after all the points are checked.

However, there is a problem that the area of

![Fig. 1 3D LIDAR point clouds before and after filtering](image-url)
buildings is possibly mixed with vegetation, and the LIDAR points in these areas cannot be separated into two objects easily. Then the intensity information of the LIDAR data can be used to solve this problem. The intensities of the LIDAR data are different from each other because of the material of targets. Meanwhile, the geometric shape characteristics can also help us to distinguish the vegetation and building because these two types of objects are significantly different in geometric shape. In fact, all the orthographs of the building in the test area are made up of regular rectangle, a rectangle restriction is added to the processing of region growing to be sure that the building and vegetation can be separated successfully.

All the discrete LIDAR points have been grouped into single objects, and we do not know weather one object is a building or a tree. Different from one single LIDAR point, one object which contains plenty of points can reflect its semantic characteristic in whole. Then we can apply our knowledge (the building's semantic characteristic) to the recognition of them.

1.3 Noise elimination

It is necessary to eliminate the influence of small “noise objects”, e.g. single tree, cars and parterre because that in size a building is much bigger than those “noise objects”, those small objects can be deleted according to a size threshold.

2 Buildings’ semantic analysis and extraction

2.1 Buildings’ semantic analysis

It is of the most importance to analyze the buildings’ semantic characteristic and to set up the semantic rules for extracting buildings. As artificial object, the building has some special characteristics. With the aid of air photo (Fig. 2), we know that, in the test area, most buildings have different space shapes, but some common characteristics about these buildings objects can be found after analysis.

Fig. 2 Air photo of test area

Firstly, the orthograph of a building is made up by some regular rectangles; secondly, although the shapes of the building roofs are various, and are flat or gabled, they are all made up by several regular planes. These characteristics determine that the LIDAR points of the building object are distributed in a special form, and on the basis of these semantic characteristics buildings can be distinguished from trees. The straight line and plane detecting operation are used to determine if one object accords with the buildings’ semantic rules, if the orthograph of the object in two-dimensional space is made up of some straight lines and the object in three-dimensional space is made up of several regular planes, then this object is considered as a building.

2.2 Building extraction using building’s semantic rules

2.2.1 Straight line detection

In our experiment, we use the classical Hough transform to detect the straight lines in the object points. Before the detection we need to transform the object points into a raster form orthograph image, and then we detect the object’s edge. In the Hough transform, a given point \((x, y)\) in an image defines a line \(y = ax + b\) in the parameter space with axes for the parameters \(a\) and \(b\). If an image contains several points on a straight line, the line of these points in the parameter space will intersect and the position of the intersection yields the parameters of the line in the image. If an image contains no straight line, the line of these points in the parameter space will not intersect in one point.
2.2.2 Plane detection

Vosselman and Dijkman present a method to extract planes from non-regularized LIDAR points using a 3D Hough transform\(^2\). Each point \((x, y, z)\) in a LIDAR dataset define a plane \(z = s_x x + s_y y + d\) in the 3D parameter space spanned by the axes of the parameters \(s_x\), \(s_y\), and \(d\), vice versa, each point in the parameters space may defines a plane in LIDAR dataset. If a LIDAR dataset contains points in a planar face, the planes of these points in the parameter space will intersect at the position which corresponds to the slope and distance of the planar face. The bin of the parameter space with the largest number of intersecting planes is selected as the parameters points of the plane in the LIDAR dataset. Of course, if a LIDAR dataset contains two or more planar face, the bins with the peak value of the intersecting planes in the parameters space will be two or more, corresponding to the plane number.

Through the analysis above, we have known that the 3D Hough transform algorithm not only can detect weather one object contains planes but also can acquire the plane number about the object. Fig. 3 shows the plane detection result of four generated object.

![Fig. 3 Plane numbers in these four object dataset respectively are 2, 1, 0 and 4](image)

2.2.3 Buildings extraction result

For each object obtained through the object generation and noise elimination processing, two algorithms discussed above, are used to recognize whether it is a building. There are 7 buildings, i.e. 7 points blocks, they are detected in the test area, and then we can reconstruct them in 3D form.

3 Reconstuction of buildings

From the air photos of the test area(Fig. 2) and the common knowledge, we can be clear about that all the buildings in the test area belong to three models: flat, gabled and hipped (Fig. 4). meanwhile, the distribution shape of points cloud in 3D space (Fig. 1(a)) also can help us to confirm them. Flat building has one flat plane; gabled roof has two planes, and it has one simple straight line whose direction is parallel to the long side of building; the ridgeline of hipped roof consist of forked line segments with different direction.

We have already got each building’s footprint, and have gained each building’s plane number by the 3D Hough transform. The buildings’ pa-