Buffer Growing Method for Road Points Extraction from LiDAR Data

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Abstract

Light Detection and Ranging (LiDAR) data has been used to detect the objects of earth surface from huge point clouds gotten from the laser scanning system equipped on airplane. According to the precision of 3~5 points per square meter, objects like buildings, cars and roads can be easily described and constructed. Many various areas, such as hydrological modeling and urban planning adopt this kind of significant data. Researchers have been engaging in finding accurate road networks from LiDAR data recent years. In this paper, A novel algorithm with regard to extracting road points from LiDAR data has been developed based on the continuity and structural characteristics of road networks.

1. Introduction

A common physical model of getting LiDAR data is based on an airborne laser scanning system, which consists of a laser scanner, a GPS receiver and Inertial Navigation System [1]. With the aid of sensor technology, the LiDAR system is able to scatter pulses of laser light striking the surfaces of the earth and measure the returning time of pulses. The traveling time of each pulse is converted into a meaningful number. This number represents the distance between the sensor and earth surface and is stored into a data storage system.

In order to recognize the existing objects on the earth's surface from massive LiDAR point clouds, many researchers have used various methods to classify them as buildings, roads, and irregular structures [2] [3] [5] [6] [7]. LiDAR data provides the intensity of surfaces along with height. Both height and intensity information are useful to extract objects [2] [3] [4] [7].

A sequential algorithm has been developed to extract road points from dense LiDAR data. The algorithm has been described in Section 2. Experimental results are discussed in Section 3. And finally, the conclusions are in Section 4.

2. Extraction of Road Points

There are numerous ways to extract the road from LiDAR point clouds in a single processor. In [4], the idea of automatic detection of roads from LiDAR data based on both height and intensity information was proposed. Every point was classified into either road or non-road groups through the hierarchical classification technique and a series of filters. In [3], road points were extracted with an extended method by a series of circled-buffers, and then were overlapped onto aerial photographs and digital maps. Two important concepts are used in the extraction method. They are appropriate filtering and classification of data points.

2.1 Initial Road Extraction

A common idea is that urban roads are connected ribbons. With this feature, all points of a road would be picked out through an extension method. First, an initial square buffer G would be built from a seed point Ps, which is defined for a specified area.

A single LiDAR data point P_i can be defined as

$$P_i = \{X_i, Y_i, Z_i, I_i\}, \tag{1}$$

where X_i, and Y_i are the surface coordinate and Z_i and I_i are its height and intensity value at that location, respectively.

Let d and d_{init} be the size of a square buffer and an initial s ize, respectively; then, if a point P_i in the LiDAR data satisfie s following relationship:

$$|X_i - X_s| < d \ and \ |Y_i - Y_d| < d \tag{2}$$

The point buffer G will be now constructed as:

$$G = \{P_s, P_1, P_2, P_3, \ldots P_i\} \tag{3}$$

G contains the seed point and a set of LiDAR points.

Choi et al. used circle buffers to extend road points [3]. However, that method required too much computational time for the circle boundary, because constructing circles are more complex than constructing squares. Therefore, in this implementation, square buffers, which simply requires subtraction and comparison, are chosen to reduce computational time.

The buffer size d varies dynamically to adapt to the different road width. All points in the buffer G are either road points or non-road points. Classification and filtering algorithms will be applied to those buffer points in order to get road points. These are described in the next section.

The main factor determining d is the point ratio R, which is defined as the ratio of road points to non-road points. Since the extraction algorithm does not know the road width, it will try to test it by enlarging d, whereas R providing an important reference.

Initially d is started from the initial buffer size $d_{init.}$ If the current ratio R is reasonable, the algorithm will enlarge d with step size d_{step} until d reaches d_{max}, as shown in Equation (4),

$$f(d)=\begin{cases} d+d_{step}, & d \le d_{\max} \quad and \quad R \ge R_t \\ d_{init}, & d > d_{\max} \quad or \quad R < R_t \end{cases} \tag{4}$$

where R_t is a constant threshold ratio.

After getting all road points in the initial buffer *G*, the algorithm will choose a random road point in it to construct another buffer.

2.2 Points Classification and Filtering

In [4], intensity information is adopted as a criterion to filter out non-road points in the feature extraction algorithm; however, it often brings noisy points (unwanted points).
Since different materials have their own physical properties, such as reflectivity, each data point can be distinguished by it s intensity value, as is shown in Table 1 [8].

<Table 1> Materials and their reflectivity

Material	***Reflectivity(%)***
White paper	Up to 100
Snow	80-90
Limestone	Up to 75
Deciduous trees	60
Dry sand	57
Wet sand	41
Coniferous trees	30
Concrete	24
Asphalt with pebbles	17
Black neoprene	5

The separability of these intensity values are enough to make rough filtering possible. According to the result of extensive sampling and analysis of massive LiDAR datasets, most of the intensity values of urban asphalt road are distributed between 8 and 17. By taking advantage of these characteristics, the ASGP algorithm can easily filter out large amount of non-road points.

To classify a road point from LiDAR data points more accurately, each point should be marked into different states during processing. There are five kinds of point states defined, and they are *Candidate* point S_c, *Standard Road* point S_r, *Fake* point S_f, *Slope* point S_s, and *Non-Road* point S_n.

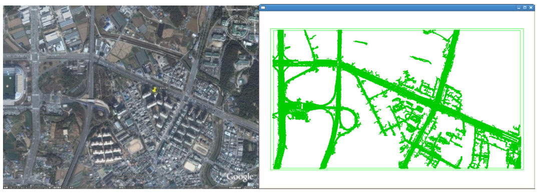
In the beginning, all points in a point buffer will be marked as *Candidate* points. After the classification and filtering algorithm is applied, *Candidate* points will be converted to one of three different states, and the conditions are shown in Equation 5. If the height H_i and intensity I_i of point P_i are under the restriction of the average values (H_{avg} and I_{avg}) of a road with their standard deviations (H_{std} and I_{std}), it will be marked as *Standard Road* point S_r. The conversion function is defined as below:

$$S(i)=\begin{cases} S_r, & H_{avg}-2H_{std} \le H_i \le H_{avg}+2H_{std} \quad and \\ & I_{avg}-2I_{std} \le I_i \le I_{avg}+2I_{std} \\ S_s, & \dfrac{|H_i-H_{seed}|}{\sqrt[2]{|P_i-P_{seed}|}} \le \tan\theta \\ S_f, & otherwise \end{cases} \tag{5}$$

In consideration of human safety, the maximum slope angle θ of normal roads is set below 16º in most countries [3]. Thus if the height of a point is satisfied with the slope condition [3], it will be marked as a *Slope* point S_s. P_{seed} is the seed point of a buffer, while H_{seed} represents the height of it. And other points are marked as *Fake* points.

3. Results

The test platform is a single PC, which contains an Intel Core™2 Duo CPU with 2G memory. The test LiDAR data, which contains approximately 6 million points, was acquired from Daejeon area, which is one of major cities in Korea is shown in the left part of Figure 1. And the extraction result is shown in the right part of below figure.



(Figure 1) Test image from LiDAR data and Result

4. Conclusion

Extracted roads are consistent with actual road network. However, there are still noisy points over the road. In some cases points were missing in narrow places. The noisy elimination algorithm may not very accuracy in some unusual places, such as parking lots and residential sub-district. The roads of these areas are wider than normal road; however, they may use the same material as road. In order to handle these kinds of problems, the more complicated algorithms will be required.

In future, a parallel framework will be developed based on this sequential algorithm to improve the efficiency of LiDAR data processing.

Acknowledgement

This work was supported by the Korea Science and Engineering Foundation (KOSEF) grant funded by the Korea government (MOST) (R01-2007-000-20577-0).

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