Pseudo-Grid Based Building Extraction Using Airborne LIDAR Data

Woosug Cho [a,*], Yoon-Seok Jwa [b], Hwi-Jeong Chang [b], Sung-Hun Lee [b]

[a] Associate Prof. Dept. of Civil Eng., Inha University, Inchon 402-751, KOREA - wcho@inha.ac.kr
[b] Graduate student, Dept. of Geoinformatic Eng., Inha University, Inchon, KOREA - yoon1314@lycos.co.kr

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ABSTRACT:

This paper proposed a practical method for building detection and extraction using airborne laser scanning data. The proposed method consists mainly of two processes: low and high level processes. The major distinction from the previous approaches is that we introduce a concept of pseudo-grid (or binning) into raw laser scanning data to avoid the loss of information and accuracy due to interpolation as well as to define the adjacency of neighboring laser point data and to speed up the processing time. The approach begins with pseudo-grid generation, noise removal, segmentation, grouping for building detection, linearization and simplification of building boundary, and building extraction in 3D vector format. To achieve the efficient processing, each step changes the domain of input data such as point and pseudo-grid accordingly. The experimental results show that the proposed method is promising.

1. INTRODUCTION

In recent years, accurate 3D data in urban areas is in great demand for many applications such as urban planning, mobile communication, 3D city modeling and virtual reality. Usually urban areas are dynamically changing due to construction and extension of urban features, especially buildings. Detection and reconstruction of buildings are of highest interest in the geospatial community. Since manual digitizing is time consuming and very costly, a fast and automated method for detecting and extracting buildings is required by many users of geographic information system (Palmer, 2001).

Airborne laser scanning is a relatively new and promising technology for obtaining Digital Surface Models (DSMs) with high density and high positional accuracy of the earth surface. The development of airborne laser scanning started in the 1970s (Schenk, 1999). Airborne laser scanning system comprised of laser scanner, GPS receiver and IMU computes the range to the target point by emitting a laser pulse and measuring the round-trip time. Contrary to the passive sensor such as optical sensor, the laser scanner is an active sensor so that it works day and night, and is less affected by the shadow and weather condition (Baltsavias, 1999).

A number of research works have been performed on building detection and reconstruction from airborne laser scanning data in automated fashion. Wang (1998) used the shape information to separate buildings from all other objects based an assumption that most buildings have simple and regular shapes and other objects do not have. The shape information is obtained from edges detected on the elevation image in regular grid that is converted from laser data. In Maas and Vosselman(1999), the authors presented two techniques for determining parameters of gable roof type building models from laser altimetry data. Both techniques work on the original laser scanner data points without the requirement of an interpolation to a regular grid.

Wang and Schenk (2000) reported an approach that takes high quality terrain surface data generated by airborne laser scanning data as input and goes through edge detection, edge classification, building points extraction, TIN model generation, and building reconstruction to extract and reconstruct buildings and building related information. For building detection, it detects edges from the surface data and classifies edges to distinguish building edges from other edges based on their geometry and shapes including orthogonality, parallelism, circularity and symmetry. Morgan and Tempfli (2000) developed a procedure starting by resampling elevation as obtained by laser scanning into regular grid. The core part of building detection is based on a morphological filter for distinguishing between terrain and non-terrain segments. The non-terrain segments are classified into building or vegetation.

In Morgan and Habib(2001), the authors generated a 3D TIN structure using the irregularly distributed laser data for building detection and extraction. The 3D TIN is generated to serve the detection of the building facades including the vertical walls. Elaksher and Bethel (2002) utilized the geometric properties of urban building for the reconstruction of the building wire-frames from the LiDAR data. The approach started by finding the candidate building points that are used to populate a plane parameter space and followed by filling the plane parameter space, extracting roof regions and refining the plane parameters. Finally, the region boundaries are extracted and used to form the building wire-frames.

In this paper, we propose a practical method for building detection and extraction in urban areas. The proposed method consists mainly of two processes: low and high level processes. The major distinction from the previous approaches is that we introduce a concept of pseudo-grid (or binning) into raw laser scanning data to avoid the loss of information and accuracy due to interpolation as well as to define the adjacency of neighboring laser point data and to speed up the processing time.

The practical approach proposed in the paper begins with pseudo-grid creation, noise removal, segmentation, grouping for building detection, linearization and simplification of building boundary, and building extraction in 3D vector format. To achieve the efficient processing, each step listed above changes the domain of input data such as point and pseudo-grid accordingly. Figure 1 illustrates the schematic diagram of the practical approach for building detection and extraction proposed in this paper.

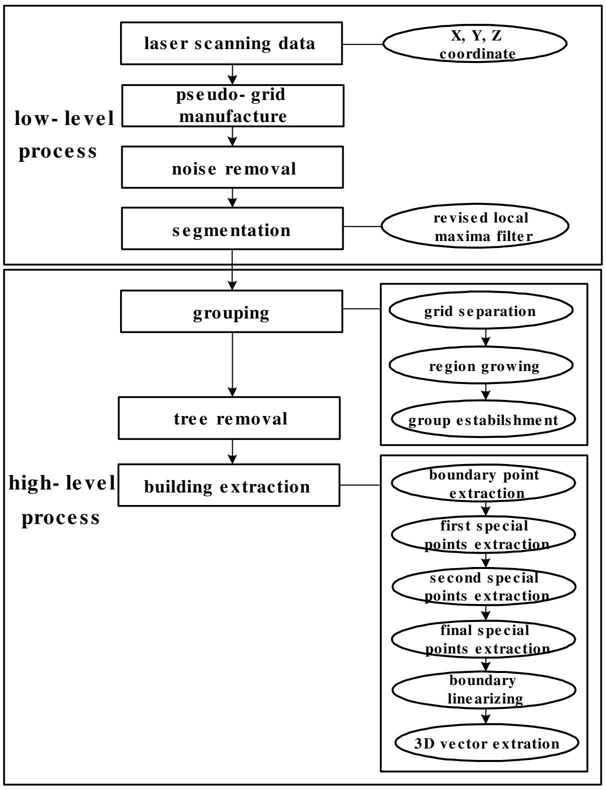

Figure 1. The schematic diagram of the proposed approach for building detection and extraction

2. BUILDING DETECTION AND EXTRACTION

The proposed approach is divided into two processes: low level and high level process. The low level process consists of pseudo-grid generation, noise removal and segmentation. The high level process consists of grouping, tree removal and building boundary extraction. In addition, each step changes the domain of input data such as laser point domain and pseudo-grid domain in order to achieve efficient data processing.

Figure 2 shows the change of data domain in the proposed approach for building detection and extraction.

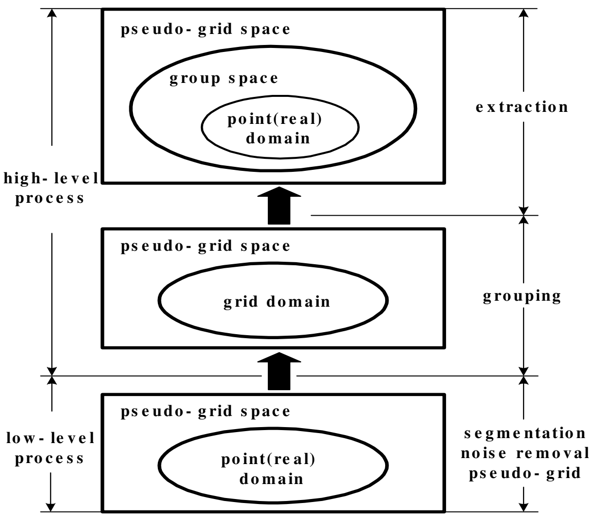

Figure 2. The change of data domain in the proposed approach for building detection and extraction process

2.1 Low-level Process

Pseudo-Grid Generation

In many previous research for building detection and extraction, irregularly distributed laser scanning data are converted into grid form so as to enhance speed of data and then building extraction is performed. In doing so, unwanted errors are introduced in the process of interpolation. In order to avoid the errors, we invented a concept of pseudo-grid that virtually contains laser point data in each grid form.

The size of pseudo-grid is calculated with average point density of laser point data. Once pseudo-grid is created, the raw laser point data is assigned to each pseudo-grid shown in Figure 3.

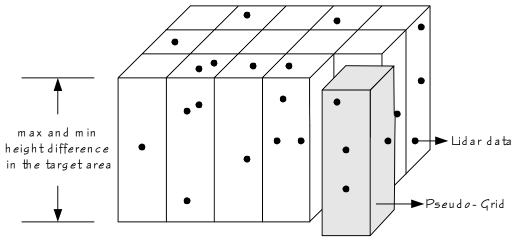

Fig. 3. Pseudo-grid generation

Since we create pseudo-grid, we don't need to convert laser point data into regular grid form and don't introduce any errors into the raw data through interpolation. In addition, the pseudo-grid improves the adjacency among laser point data so as to speed up the process such as building detection and extraction.

Noise removal

There are irregular random errors contained in raw laser point data caused by instrument malfunction, natural phenomena and so on. In this paper, we only consider random errors such as outliers and remove them by statistical method.

Segmentation

It is defined here that segmentation is only to extract building candidate points from laser data point cloud. We applied a local maxima filter for segmentation.

2.2 High-level Process

Grouping

The process of grouping is performed on pseudo-grid domain and defined as classifying laser point data as a group resulted from segmentation above. After grouping, we can compute the area and perimeter length of each group, which will be used for building decision criteria.

Tree removal

After grouping, the laser points belonging to trees still exist as building candidates. Those laser points could be removed by two simple measures: minimum building area and circularity. However, some of laser points belonging to trees can't be eliminated if their size and shape are similar to buildings.

Extraction of building boundary

The process of extracting building boundary is performed on both point and pseudo-grid domain. The boundary of each group is linearized and simplified, and then interest points corresponding to building corners are extracted.

Figure 4 shows one example of interest points extraction process.

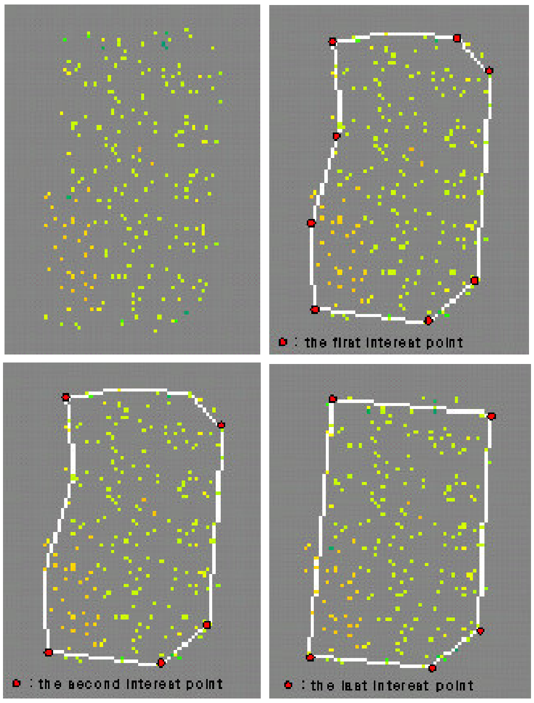

Figure 4. Interest points extraction process(example)

3. EXPERIMENT RESULTS

The target area is located at Chungjoo city in Korea and its size is about 1,100m(width)×750m(length). The equipment was Optech's ALTM 1020. The flight height, flying speed, laser repetition rate, swath width, width overlapping, and average point density per pass are 1000m, 180 km/h, 5,000 Hz, 450 m, 87%, and 0.2/□, respectively. The threshold values for minimum building height and area are 5m and 50 □, respectively.

The raw laser scanning data of the target area is shown in Figure 5.

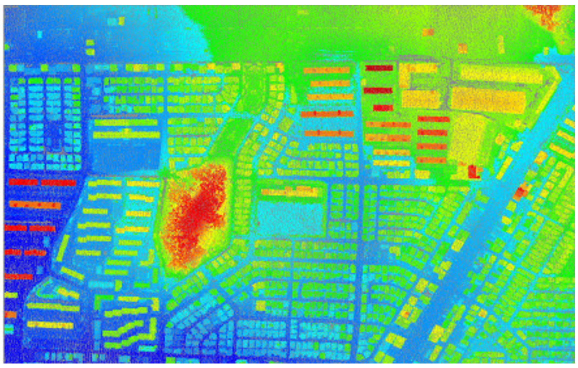

Figure 5. Raw laser scanning data of target area

Figure 6 and 7 show the results after noise removal, segmentation, tree removal and grouping, respectively.

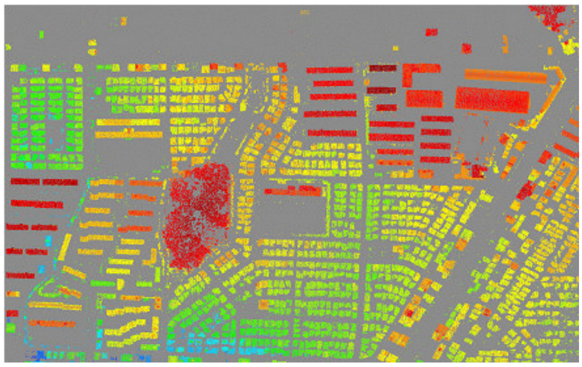

Figure 6. Result after noise removal and segmentation

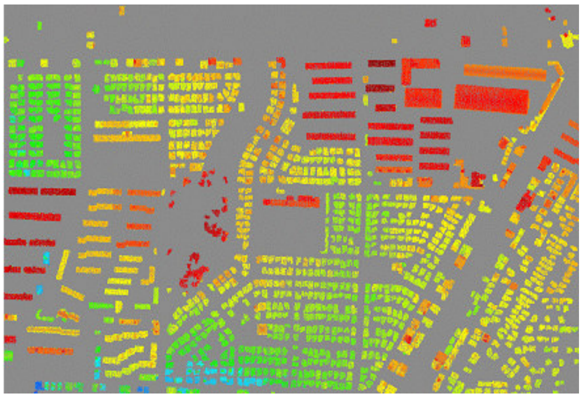

Figure 7. Result after tree removal and grouping

Figure 8 and 9 show the final results for buildings extracted in 3D vector format from top and perspective view, respectively.

Figure 8. Final result for buildings in 3D vector format.(TOP)

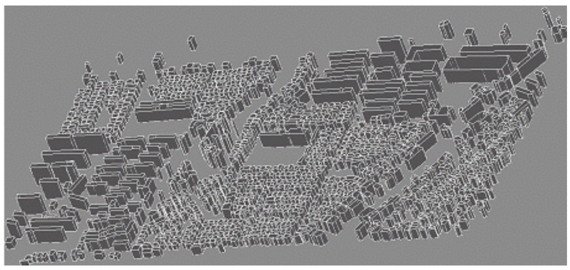

Figure 9. Final result for buildings in 3D vector format.

4. CONCLUSIONS

In this paper, we introduced a concept of pseudo-grid into raw laser scanning data to avoid the loss of information and accuracy due to interpolation as well as to define the adjacency of neighboring laser point data and to speed up the processing time.

However, the proposed approach suffered from separating trees and buildings. It should be mentioned here that a simple measure such as circularity and height difference is not enough to differentiate them. In order to overcome the drawbacks, we need to incorporate new approach such as data fusion into the proposed approach. Nevertheless, we could conclude that the proposed approach is promising for building detection and extraction in automatic fashion.

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