A Research for the Extraction of 3D Urban Building By Using Airborne Laser Scanner Data

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ABSTRACT:

This paper will focus on the extraction of 3D urban building from ALS (Airborne Laser Scanner) data in built-up areas with the incorporation of GIS data. Sample terrain points are firstly captured by the integration of normalized DMS data and GIS road network data. Rough DEM is interpolated from the sample terrain points, which make it possible to extract potential building by subtracting from DSM data. Due to the vegetation areas may close to buildings and probably melted together in the DSM, low-rise building and high-rise building segments are discriminated based on local height information. A method to remove building noises by multi-criterions such as building size, building height and roof smooth, is proposed. The test is selected at a high-density building region in Tokyo with a 50cm × 50cm resolution ALS data. A comparing with orthographic aerial photograph is taken to evaluate the extracting accuracy. Results show a high accuracy can be achieved to extract building with the method proposed in this paper.

1. INTRODUCTION

With the increasing number of applications of Digital Surface Models (DSMs) in urban areas, such as digital orthophoto production, 3D city modelling and 3D building reconstruction (Wehr and Lohr, 1999; Ackermann, 1999), Laser scanning has been recognized as an accurate data source for DSM generation in urban areas (Haala et al., 1997), due to its advantages as an active technique for reliable 3-D point determination without requirements towards surface reflectance variations and time consuming error-prone matching techniques. One of the main attribute affecting 3D city modelling algorithms is point density, which is dependent on several factors, such as flying height, flying speed and scanner frequency (Lemmens et al., 1997).

Comparing to photogrammetric techniques, airborne laser scanning technology has benefits for the generation of DTM or DSM, although there are limiting factors due to the laser data having no structural and textural information (Baltsavias, 1999). A number of authors have paid their attentions on the approach to generate 3-D building models mainly or solely based on airborne laser scanning data. Their research approaches are focus on the extraction of building roof primitives from dense laser altimetry data. For example, to extract planar roof primitives by a planar segmentation algorithm, using additional ground plan information for gaining knowledge on topological relations between roof planes. (Haala and Brenner, 1997); to derive heights for roof-less cube type building primitives by the fusion of laser-altimeter data with a topographical database (Lemmens. et al. 1997); to derive parameters for 3-D CAD models of basic building primitives based on least-squares adjustment minimizing the distance between a laser scanning digital surface model and corresponding points on one of the four standard building primitives, in which the boundaries of buildings are derived from ground plans (Haala et al. 1998); and to determine building models from original laser scanner data points without the requirement of an interpolation to a regular grid based on a tin interpolation method (Maas and Vosselman, 1999). But in the real world, it is almost impossible to describe all kinds of buildings using comprehensive building models.

A simple combination of digital laser and multispectral image data is another research aspect for building, trees and grass-covered areas extraction. The basic idea for integrating two kinds of data can be described by the following reasons. Due to the restriction to surface geometry, the number of object types, which can be discriminated within a DSM is very limited. Multispectral data is helpful for digital laser to get a further differentiation like the extraction of streets or landuse classes is not possible. In other hand, a problem while classifying multispectral data is the similar reflectance of trees and grass-covered areas. But trees and buildings can be discriminated easily from grasscovered areas or streets using height data, since they are higher than their surroundings, whereas streets and grass-covered areas are at the terrain level (Brunn and Weidner, 1997; Haala and Brenner, 1999).

A new approach covering the detection of buildings using DSM as input data and with the incorporating of GIS data is proposed. In this approach GIS road network information is used as a known land use class, and combined with geometric information from a laser scanner DSM to extract rough DEM. Then primary discrimination of building is taken by the overlay with ALS data. Finally building noises in primary discrimination are removed by multi-criterions such as building area, building height and roughness.

2. METHODOLOGY

2.1 Description of building detection

The description of the approach to discriminate building from airborne laser scanning data is shown in Figure 1. The subsequent steps are to compute the normalized DSM; to binarize this data set using an interpolated rough DEM yielding an initial segmentation, to adapt the threshold based on local height information, which leads to the refined segmentation, and to detect building from possible low-rise building and high-rise building segments by multi-criterions.

Possible low-rise buildings and possible high-rise buildings are binarized from refined segmentation based on local height information. The roughness of the surface measured by differential geometric quantities is calculated as an important criterion for the discrimination of buildings and vegetations. Due to there be possible melting between low-rise buildings and vegetations, a splitting and merging process is used to drive closed areas. Finally, valid building segments are evaluated and selected by region size and roughness.

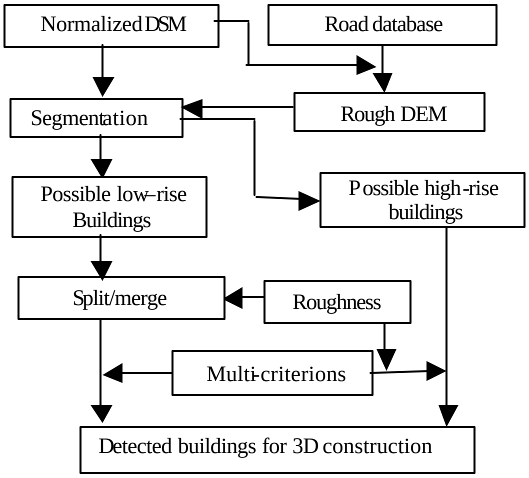

Figure 1. Flowchart for detecting building

2.2 Capture of DEM

DEM generation in built-up areas is originally derived from the removing of buildings and constructions, which masking the ground surface. So the recognition and capture of buildings is an important independent task before DEM generation. In our test, DEM is captured before the detection of building and the discrimination of building are taken by the removing of DEM from DSM. So the accuracy of DEM becomes less important here. In fact, due to the restriction to surface geometry in urban area, the number of object types, which can be discriminated within a DSM is very limited. Street classes will be very helpful for us to capture a rough urban DEM, because there is a density road net in urban area and each building is accessible.

There are three kinds of roads in out test: railway, viaduct, and original street (road). Only original streets are used and overlay with Airborne Laser Scanner data. Sample points are selected by the evaluation of roughness along the street. Based on the altitude information at sample points, height $\tilde{h}_j$ at an unsampled location of interest *j* can be estimated from the nearby sampled locations (stations) *i* according

$$\tilde{h}_j = \sum_{i=1}^{n} (w_i \times h_i) \Big/ \sum_{i=1}^{n} w_i \qquad (1)$$

to

where *n* is the number of nearby stations that influence the estimate at location *j* , h_i is height at sample point *i*, and w_i is some funtion of the inverse distance between point *i* and location *j*.

2.3 Discrimination of Building

Detection of building is mainly start from the segmentation image derived by overlay of normalized DSM and rough DEM. Segmentation image includes the height information of building or vegetation. Firstly, the roughness of the surface measured by differential geometric quantities such as gradients can be derived, and will be an important criterion in the detection of buildings. Then possible low-rise building segments and high-rise building segments are binarized based on a threshold of local vegetation height information. Due to the vegetation areas may close to buildings and probably melted together in the DSM, a splitting and merging process is working on the possible low-rise building area to merge closed pixels, and valid segments are evaluated by the multi-criterions.

Segment size, minimum standard deviation, and adjoining relationship are the main criterions used to detect low-rise buildings. Size criterion is used in order to reject spurious segments, e.g. due to single trees. All segment containing less members than a predefined number of pixels are eliminated. But for this selection, it is not sufficient for larger vegetation areas or vegetation areas close to buildings. So segments will be split, if the standard deviation is larger than the specified threshold. Neighboring segments are merged, if the segments share the same boundary. Due to the complication of general configuration of the urban's surface, spurious segments such as hill may mix high-rise buildings, which will be rejected by average roughness criterion. Before the calculation of average roughness, we should identify the same plane region in each segment. If the close pixels have a similar roughness and the area is big than a threshold, we call the region as same plane region, the calculation of average roughness R_i in segment *i* can be given as following:

$$R_i = \Sigma P_{ij}/N \qquad (2)$$

where P_{ij} is the pixel *j* which belongs to one of the plane regions in segment *i*. N is the total pixel number of

3. RESULTS AND DISCUSSIONS

Our test is selected at a build-in area in Tokyo, Japan. Figure 2 shows the corresponding normalized DSM, which was provided by the laser scanner-system in 2001; terrain points were measured at approximately one point each 1×1 m^2 with an accuracy of 0.5 m. Figure 3 shows a polygon road data in this area.

Figure 2. Normalized DSM

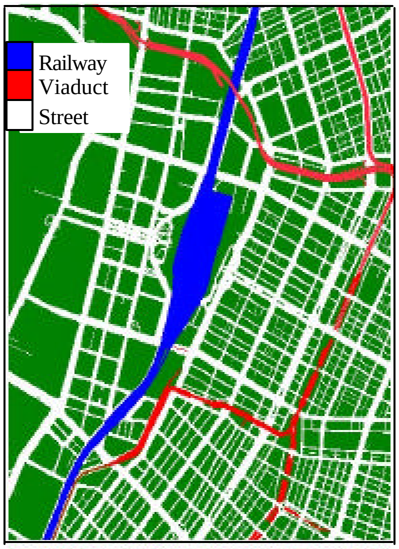

Figure 3. Road network data

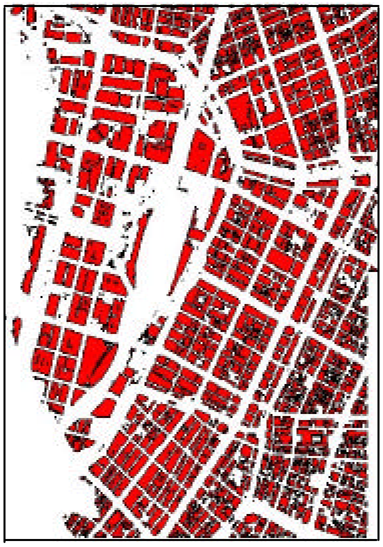

Figure 4. Segmentation area

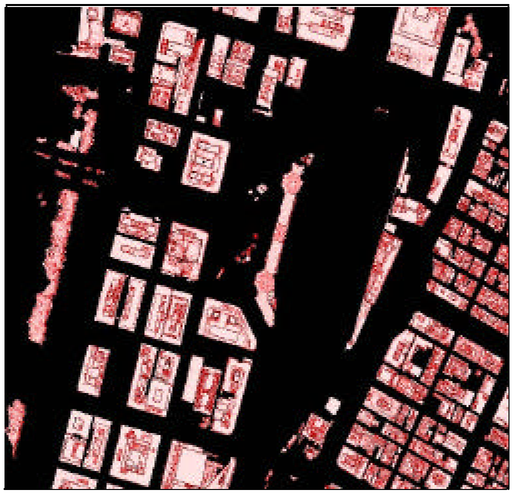

Figure 5. Roughness of segmentation area

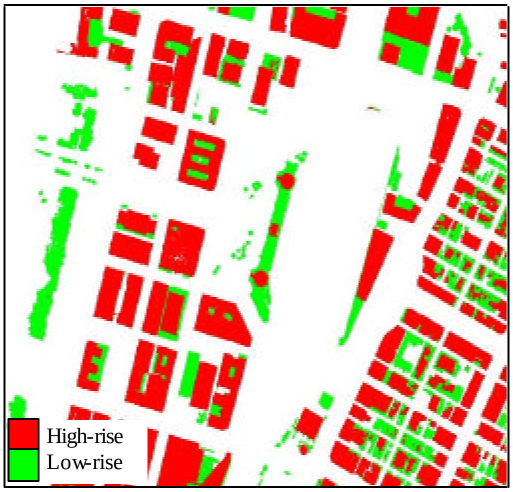

Figure 6. Discrimination of high-rise building

Based on this normalized DSM and road database, terrain surface sample points alone road can be can be captured and used to interpolate rough DEM. This rough DEM can then be subtracted ¨from the original DSM. Figure 4 shows subtracted segmentation with a threshold of local building height information. The detection of building areas within this segmentation is mainly based on roughness of the segmented surface, which is shown in Figure 5. After reclassified low-rise building areas (Figure 6) using the expected roughness of vegetation as threshold, multi-criterions are used to discriminate between buildings and trees in both low-rise and high-rise building areas. Figure 7 displays the detected tree areas and building areas.

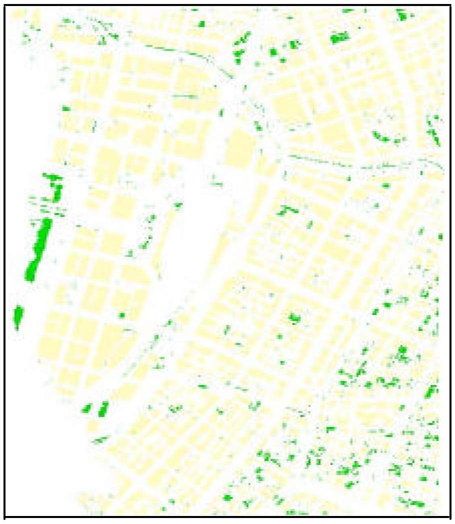

Figure 7. Discriminated trees

Figure 8. Discriminated buildings

The discriminated building results have been overlaid with the orthographic aerial photograph took in 2000 for the accuracy assessment. Figure 8 shows the distribution of the overlaid result. For comparison, we found the building extraction from laser scanning DSM by using the method proposed in this paper is very high. The extraction accuracy of building in build-in area is above 92 percent at this test. It can not only detect larger vegetation areas, but also discriminate vegetation areas close to buildings.

4. CONCLUSIONS

Data collection in urban environments can profit considerably if laser scanning is applied. The separation of normalized DSM data into regions representing buildings can be improved significantly, if GIS road network data is utilized as additional information for the capture of DEM in build-in area. This normalized DSM gives information on the height above ground for each image pixel and can be derived from laser scanning data. Different methods are developed for the extraction of low-rise buildings and high-rise buildings by multi-criterions due to the different configuration and spatial distribution for their segmentations. The comparison of extracting buildings with orthographic aerial photograph shows that automatic building extraction from laser scanning DSM is proved to be very successful, and the use of this information is strongly recommended during the automatic generation of urban databases.

The new approach covers the detection of 3D urban building using DSM as input data with the incorporation of GIS road network data. Further researches, such as the use of height data for 3D building reconstruction with suitable building modeling or integration ALS data with aerial photograph data to improve extraction accuracy of building, are necessary in the next step

REFERENCE

Ackermann, F., 1999. Airborne laser scanning—present status and future expectations. Journal of Photogrammetry & Remote Sensing, 54, pp64–67.

Baltsavias, E.P., 1999, A comparison between photogrammetry and laser scanning. Journal of Photogrammetry & Remote Sensing. 54, pp83–94.

Brunn, A., Weidner, U., 1997. Extracting buildings from digital surface models. Vol. 32, IAPRS, Part 3-4W2, Stuttgart, Germany, pp. 27–34.

Haala, N., Brenner, C., Anders, K.-H., 1998. 3D Urban GIS from Laser Altimeter and 2D Map Data. Vol. 32, IAPRS, Part 3r1, Columbus, OH, pp. 339–346.

Haala, N., Brenner, C., Anders, K.H., 1997. Generation of 3D City Models from digital surface models and 2D GIS. International Archives of Photogrammetry and Remote Sensing 32, 68–75, Part 3–4 W 2.

Hug, Ch., Wehr, A., 1997. Detecting and identifying topographic objects in imaging laser altimetry data. IAPRS 32, 19–26, Part 3-4W2.

Lemmens, M., Deijkers, H., Looman, P., 1997. Building detection by fusing airborne laser-altimeter DEMs and 2D digital maps. International Archives of Photogrammetry and Remote Sensing. 32 (3-4W2), pp42– 49.

Maas, H.G. and Vosselman, G., 1999, Two algorithms for extracting building models from raw laser altimetry data. Journal of Photogrammetry & Remote Sensing. 54, pp153–163

Wehr, A. and Lohr, U., 1999, Airborne laser scanning—an introduction and overview. Journal of Photogrammetry & Remote Sensing. 54, pp68–82.