WAVELET AND SCALE-SPACE THEORY IN SEGMENTATION OF AIRBORNE LASER SCANNER DATA

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ABSTRACT: An important property of any object in the world is that it only appears over a certain ranges of scales. Therefore, the scales should be considered in describing or analyzing of an object. Scale-space theory has been well developed in computer vision. Recent years, wavelet, a new and impressive mathematical tool, which can be said as an evolution of scale-space theory, has raised the consideration of the scientists in many fields including geoinfomatics. Based on the idea well developed in pattern recognition, this paper is aimed to introduce the application of wavelet in segmentation algorithms of airborne laser scanner. In this paper, a segmentation wavelet based framework was set up. Afterwards, several experiments applied in testing site were done to prove the feasibility of proposed method in segmentation of airborne laser scanner data. This work is only a part of author's doctoral dissertation. As a consequence, this paper only presents the preliminary results of this work and the further developments will be pointed out.

1. INTRODUCTION

Airborne laser scanner was introduced as a high accurate tool for topographic mapping. There have been several attempts in both research and application to utilize this useful tool. However, the algorithm for segmentation of this kind of data, i.e. distinguish between ground surface and objects on the surface, is still on going researched. Several recent researches can be listed as Haala et al. 1998 derive parameters for 3-D CAD models of basic building primitives by least-squares adjustment minimizing the distance between a laser scanning digital surface model and corresponding points on a building primitive; Axelsson, 1999 introduced the classification algorithm based on the Minimum Description Length criterion; Maas and Vosselman, 1999 proposed two algorithms for extracting building from raw laser data; Haala et al. 1999 integrated multi-spectral imagery and laser scanner data to extract buildings and trees in urban environment. This research is aim to follow these attempts with a new approach, i.e. usage of scale information.

As been known, an important property of any object in the world is that it exists as a meaningful entity in the certain ranges of scale. Therefore, object appears in different ways depending on the scales of observation. Consequently, the analysis must depend on the scale of observation called multi-scale representation. Especially, the need of multi-scale representation is increasing when automatically deriving information from the acquired signals of objects in the worlds, like feature classification, feature extraction. Then, a very important question is opened; with a specific object, what the proper scale for information extraction is. In normal case, it is not obvious to determine in advance this proper scale. Therefore, the analysis of object should take over the whole scale space and then the proper scale is selected. Scale-space theory is a general framework that is generated by the computer vision theory for representing image data and the multi-scale nature of it at the very earliest stages in the chain of visual processing that is aims at understanding (perception) (Lindeberg, 1994).

Wavelet, which can be called an evolution of scale space theory, is linear scale space representation, which developed by many scientists from different fields and based on a solid mathematical background. The first idea of wavelet system was introduced by Alfred Haar in 1910. However, it has been mostly developed since last fifteen years in connection with many older ideas from other fields. The fundamental idea of wavelet is to analyze the signal according to scale or resolution. In this paper, a wavelet-based feature extraction method that is based on the algorithm introduced by Mallat and Zhong, 1992 was utilized in airborne laser scanner data. By utilizing the scale information, the difficulty in segmentation of airborne laser scanner was decreased.

2. METHODOLOGY

Airborne laser scanner data (see Table 1) provided by Kokusai Kogyo Co., Ltd. Geomatics Department with the acquired site in Japan was used in this research. The summarized flow chart of processing is illustrated in Figure 1 below.

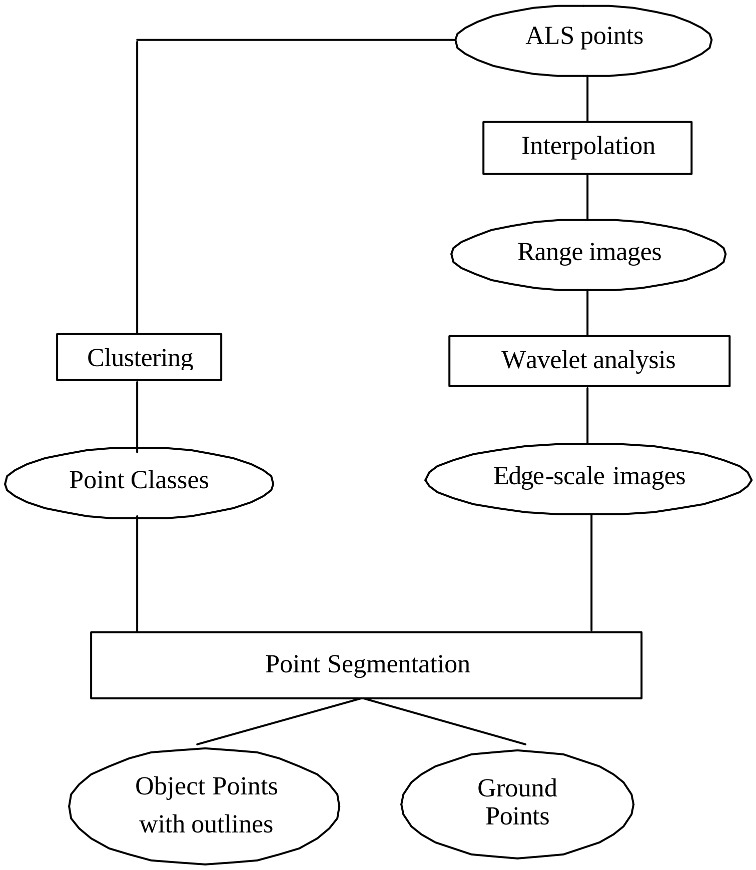


Figure 1 – Flowchart of processing

Table1 – Airborne Laser Data characteristics

Operation Altitude	10,000 feet AGL max
Scan Swath Width	200m - 2000m
FOV	45 degrees max
Pulse Rate	15Khz max
Returns	5 @ 15Khz
Cross Track Spacing	1-8 meters
Along Track Spacing	2.5 - ? Meters (aircraft speed dependent)
X, Y Positional Accuracy	0.3 meters RMSE absolute
Z Positional Accuracy	0.15 meters RMSE absolute

3. RESULT AND DISCUSSION

After flying, a set of points with X, Y, Z value was acquired. In this paper, the study area with high density of building was considered; it is Roppongi region of Tokyo City, Japan. As mentioned, full information of object in 3-dimension space was considered in this paper in which the height information was analyzed through Z value of airborne laser points and the size of objects in horizontal plane through scale analysis, i.e. wavelet analysis.

To segment airborne laser scanner points in height, K-mean clustering was applied in Z value. Depending on the knowledge about study area, the number of class was given for driving the clustering. The result of K-mean clustering of our testing is illustrated in Figure 2 below. Being separated well by K-mean clustering of Z value, the airborne laser points presents three classes: high building, ground and others. There is an ambiguity in the third class, i.e. low building, highway and tree. However, these kinds of objects have different sizes in horizontal plane that might be distinguished by scale analysis.

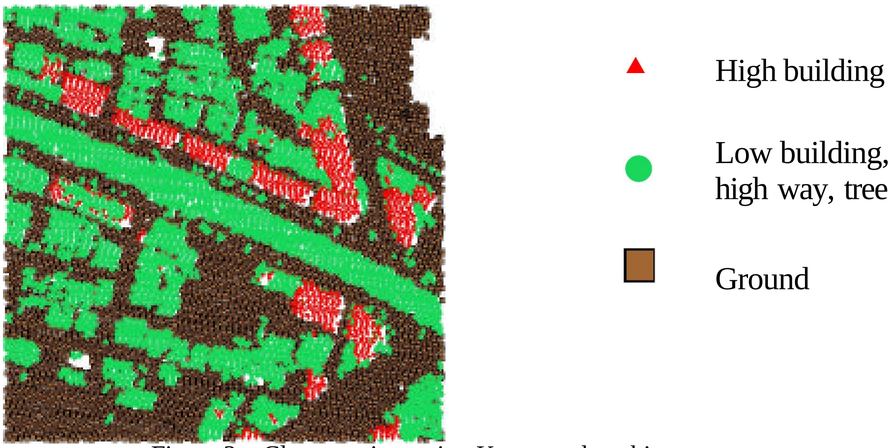


Figure 2 – Cluster points using K-mean algorthim

Before utilizing of wavelet analysis, airborne laser points were interpolated to grid in which the laser data points have been triangulated, and then from irregular to regular grid. As a consequence, the range image is shown in Figure 3 with the grid size of 0.5 meter.

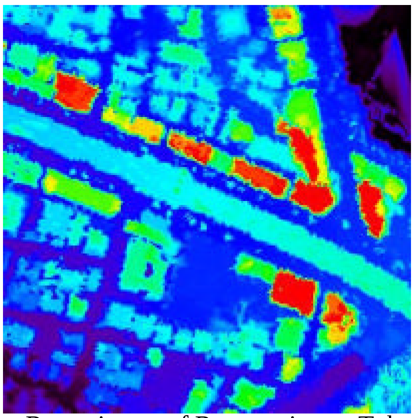
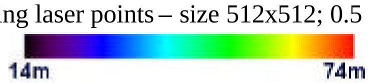
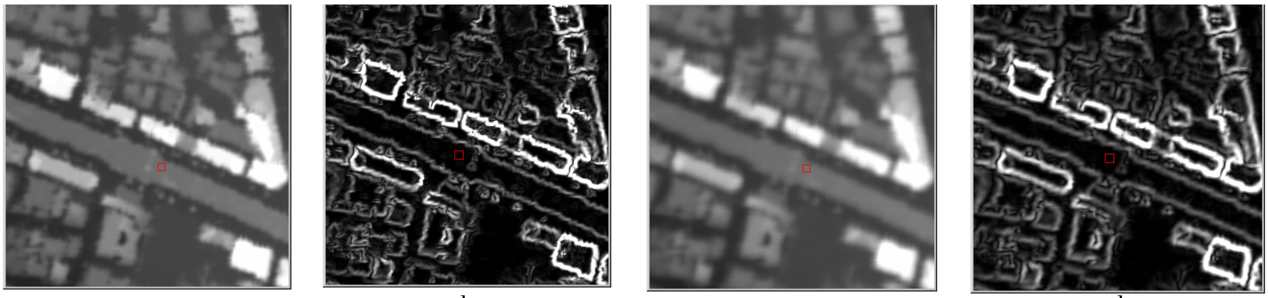


Figure 3 – Range image of Roppongi area, Tokyo, Japan
generated by rasterizing laser points – size 512x512; 0.5 meter grid size (right)



The wavelet-based method proposed by Mallat and Zhong, 1992, which illustrated the equivalence of multi-scale Canny edge detector and detecting modulus maxima in two-dimensional dyadic wavelet transform, was implemented in this research for airborne laser scanner data. The general idea can be expressed as follow. The dyadic wavelet transform generated the smooth version of range images at several scales depending on the given number of maximum scale. Let S_1 and S_2 are two successive scales. The edges of objects with size in the range of S_1 and S_2 appeared in the differences between smooth version at scale S_1 and one at S_2. These results are presented in Figure 4 below in which the different smooth versions of range images are shown along with edge images. Due to the limitation of paper length, only two examples of smooth images are illustrated here. As can be seen easily in Figure 4, some details were disappeared when moving to the coarser scale. The remained task is how to select the proper scale of each kind of objects on the Earth surface.



a b c d

Figure 4 – Smooth image at 2m (a) and modulus edge image 1m-2m (b)
Smooth image at 4m (c) and modulus edge image 2m-4m (d)

Based on the signature of edge in scale space, the selection of proper scales for each kind of objects was done. As a consequence, there were three kinds of objects that could be distinguished, say high way, building and tree. This segmentation (see Figure 5) was converted to vector format in order to use for the combined segmentation later with laser points. Due to the complicated scene in the urban area, i.e. high density of building, the segmentation based on the edge introduced some ambiguity, especially when the building is a block of some others. This problem can be adjusted by using paper map. With the purpose to illustrate the capability of wavelet-based method, this paper did not validate with paper map as mentioned. The result shown in Figure 5, then, was used for combined segmentation with laser point clusters.

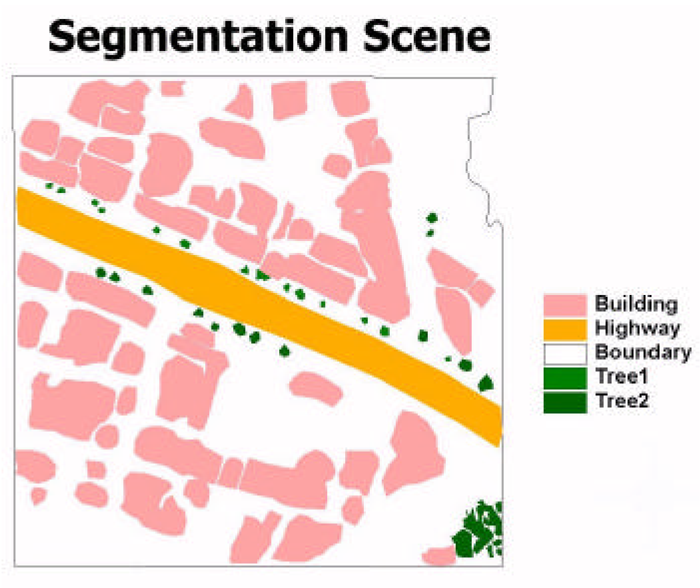


Figure 5 – Scale space segmentation result

The combined segmentation was based on a developed vector-based algorithm, i.e. point in polygon. As a result, the points were classified as ground points and object points. These two sets of point, afterwards, were triangulated to generate the Digital Terrain Model - DTM (bare Earth surface) and Digital Surface Model – DSM (with objects) as can be seen in Figure 6. The missing ground points due to the covered objects were found by interpolation from the existing ground points.

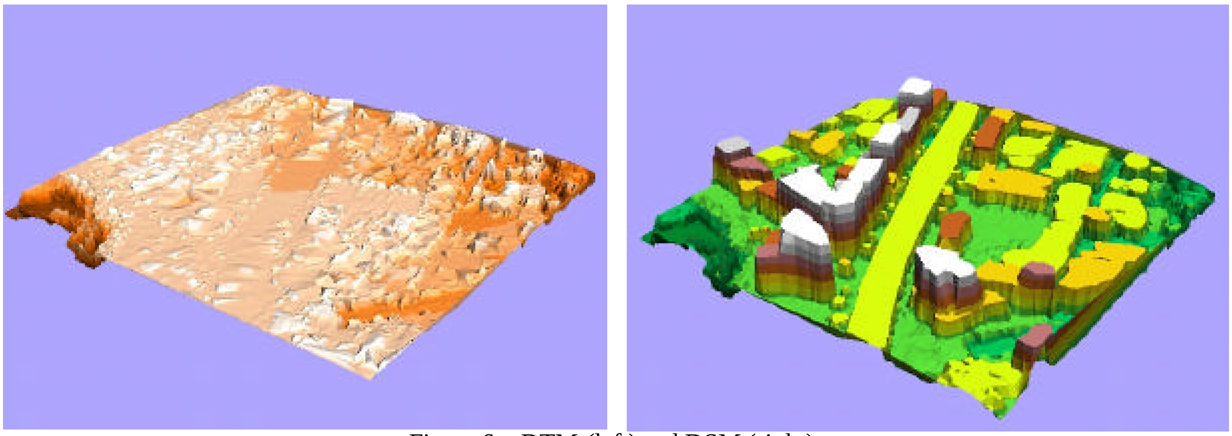


Figure 6 – DTM (left) and DSM (right)

This paper is just a part of author's doctoral dissertation in which a full automatic segmentation framework will be developed. Therefore, only some preliminary results were presented in this paper. The validation of results as well as the assessment of algorithm capability should be done and will be presented in the next papers. In addition, this developed algorithm should be tested in several kinds of sites, which cannot be done due to the limitation of time and data.

4. CONCLUSION

In summary, a semi-automatic segmentation algorithm that is based on wavelet was developed. The idea to apply wavelet in segmentation of airborne laser scanner data is introduced the first time in this paper. It was generated from the idea how to use efficiently the acquired information in three-dimension space. The testing results on Roppongi area of Tokyo city proved the feasibility of this algorithm. However, this algorithm has not been tested in the more complicated area, e.g. more kinds of covered objects, which might introduce more ambiguity in segmentation. In the further improvements, the full automatic segmentation algorithm will be developed. The quantitative assessment of testing results in several different kinds of area and computation efficiency will be done to illustrate the capability of developed algorithm. In addition, the fusion of other data sources might be performed to clarify the ambiguity in segmentation.

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REFERENCES

Axelsson, P., 1999. Processing of laser scanner data – algorithms and applications. ISPRS Journal of Photogrammetry & Remote Sensing, 54, pp. 138-147.

Haala, N. and Brenner, C., 1999. Extraction of buildings and trees in urban environment. ISPRS Journal of Photogrammetry & Remote Sensing, 54, pp. 130-137.

Lindeberg, T., 1994. Scale-space theory: a basic tool for analyzing structures at different scales. Journal of Applied Statistics, 21(2), pp. 225-270.

Maas, H. G. and Vosselman, G., 1999. Two algorithms for extracting building models from raw laser altimetry data. ISPRS Journal of Photogrammetry & Remote Sensing, 54, pp. 153-163.

Mallat, S., 1998. A Wavelet tour of signal processing. Academic Press, UK.

Prasad, L., and Iyengar, S. S., 1997. Wavelet Analysis with application to image processing. CRC Press LLC, Florida, USA.