EFFICENT SOLUTION TO DEVELOP BUILDING INVENTORY DATABASE WITH LIDAR OBSERVATION

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SUMMARY

Our current research focuses in developing an efficient solution to generate and update the building inventory database. Conventionally, the geo-database has been updated mainly based on the acquired aerial photographs. It suffers from the problems of shadow, poor contrast and occlusion. To avoid those problems, we propose the employment of LiDAR (Light Detection And Ranging) data in developing the database. It is proposed as the primary source providing geo-data for generating new database or updating the existing database. This paper reports our recent development in classification of the buildings using LiDAR data. It is the most important part of the proposed LiDAR-based solution. LiDAR data observing Roppongi, Tokyo, Japan is used to demonstrate the competence of the proposed method.

INTRODUCTION

Building inventory database plays very important role in disaster assessment. To keep pace with the rapid changes in urban areas, it must be frequently updated. The conventional method comprises the interpretation of the aerial photographs, map compilation, digitization, and field survey to input other attribute data including the number of story. This procedure is very time-consuming. More importantly, it is mainly based on the aerial photograph which suffers from the problems of shadow, occlusion and poor contrast. In addition, ortho-rectification using a precise Digital Elevation Model is required. Therefore, we propose the employment of LiDAR (Light Detection And Ranging) as primary data in a fusion scheme with other data sources to replace the current method.

Basic theory of LiDAR is measuring the time delay between emitting laser pulse and its reflected pulse to obtain the point clouds of X, Y, Z coordinates and intensity of reflected pulses. The wavelength of laser pulse is about 900-1050nm in the infrared portion of the electromagnetic spectrum. A LiDAR surveying flight equips a laser scanner system, a Global Positioning System (GPS), and an Inertial Navigation System (INS). Current LiDAR sensors have the capability of multi-echo lasers to record both first pulses and last pulses. While the development of LiDAR sensor has become a mature technology, LiDAR post-processing is still under-developed. The existing algorithms are not fully reliable (Dowman, 2004). Focused algorithms include derivation of the bare-earth surface (Sithole and Vosselman, 2004) and building reconstruction for 3D city modeling such as Maas and Vosselman (1999). LiDAR applications are continually broaden to hazard mapping such as flood mapping (FEMA, 2001) or earthquake damage detection (Steinle, 2001). Recently, it has been concerned in change detection and map updating such as Olsen (2004) and Walter (2004) with TOP10DK and ATKIS map database, respectively.

Using LiDAR as primary data, our proposed solution comprises several modules to make it more flexible in serving for several purposes by choosing several options of the available data. Each of them has been separately developed and will be added into a complete processing package. Some recent outcomes have been published elsewhere such as matching LiDAR and GIS database (Vu el al., 2004a) or LiDAR-based change detection (Vu el al., 2004b). This paper firstly describes the proposed LiDAR-based solution and then focuses in the module of LiDAR-based classification which has been developing.

LiDAR-BASED SOLUTION FOR DEVELOPING THE BUILDING INVENTORY DATABASE

The sketch of our proposed solution is depicted in Figure 1. While LiDAR data is used as primary data, spectral information derived from aerial photographs or other sources is used as supplemental information. The back-borne of processing is based on scale space processing. Detailed theory of scale space processing can be seen in Acton and Mukherjee (2000) and our implementation was described in Vu et al. (2004b). Reflected LiDAR pulses form the Earth's surface model, named Digital Surface Model (DSM). But many applications require the bare-earth model (Digital Terrain Model or DTM) rather than that DSM. The difference between surface model and bare-earth model presents the heights of overlaying objects. It can be called Digital Height Model (DHM) to distinguish it from DSM and DTM.

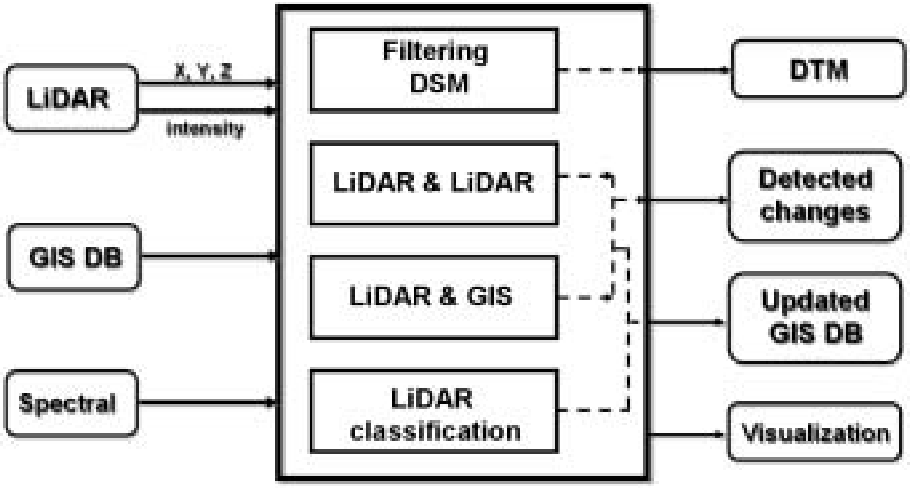


Figure 1. LiDAR-based processing system to update the building inventory database.

First module is to derive DTM from DSM applies wavelet-based method (Vu and Tokunaga, 2004). It is in improvement with non-linear scale space. Second module is change detection using two LiDAR surveying flights (Vu et al, 2004b). It is applicable when two LiDAR data sets are available. It is also applicable for damage detection if the second flight is carried out after a catastrophe. The objective of matching between LiDAR and GIS (Vu et al, 2004a) is two fold. On one hand, it is used in the case only one LiDAR data set is available for change detection or updating database. On another hand, it is to match the detected changes and GIS database. LiDAR classification with the assisted spectral information is to fulfill the updating building inventory database. LiDAR coordinates can provide shape, size and height of buildings and spectral information including LiDAR intensity assists the detection of building types. Three-dimensional visualization is additional tool to present all products in more attractive way.

LiDAR-BASED CLASSIFICATION

Sizes, height and roof material of a building have strong correlation with its usage type. LiDAR provides very dense point clouds with X, Y and Z coordinates, it is applicable to classify the buildings based on their sizes and heights from that point clouds. Additionally, pulse intensity might provide more useful cue for classification of roof material. The classification is applied on grid-format of DHM. Therefore, first module deriving of DTM should be carried out prior to this classification.

Non-linear scale space classification is employed in our classification of LiDAR data to overcome the drawbacks of the conventional classification. Those methods, supervised or unsupervised classification, are mostly pixel-based and fixed scale processing. As a result, intra-object error in classification is the big problem and objects are smashed into the fragments. Non-linear scale space has been proposed in classification (Acton and Mukherjee, 2000). Non-linear scale space classification based on area morphology showed very good results in classification and forming the objects. In classification of DHM image, we apply this non-linear scale space scheme with our approximate implementation based on morphological opening and reconstruction (Vincent, 1993). Detailed processing is described step-by-step as follow.

As mentioned above, non-linear scale space is based on area morphology. The basic idea of opening area morphology $S \; o \; s$ is the removal of all components of area less than s in the set S where o stands for opening operator (Acton and Mukherjee, 2000). Different from the basic opening morphology, area operator is amorphous. It is useful to classify the objects across scale space without rounding the object's corner, and hence, without loosing the object's details. The drawback of this method is time consuming. The approximate implementation based on morphological opening and reconstruction (Vincent, 1993) shows much faster computation. Let call original image is *MASK I* and opening filtered is *MASKER J*. The reconstruction of $\rho_I (J)$ of *MASK I* from *MARKER J* is the union of the connected components that contain at least one pixel of *J*. The opening operator used here is basic cross-shapes or flat kernel with increased sizes according to the chosen range of scales. The result of non-linear scale space analysis of

DHM is the classes of objects based on their sizes and heights.

However, trees and bushes still remain in the classified objects. It is possible to remove them from buildings and other man-made objects using NDVI which requires spectral information of Red and Near-Infrared bands. Fortunately, current LiDAR surveying flights record the intensity of reflected pulses which are about 900-1050 nm in the infrared. Those flights also equip a digital camera to acquire color aerial photographs. We simulate the near-infrared channel from this pulse intensity and incorporate it with Red channel of the aerial photograph to compute NDVI. The simple thresholding of NDVI can discriminate between vegetation and others.

Finally, classified blobs based upon object's sizes and heights are used as the mask to group the laser points. Depending on each study area, the number of class is various. Normally, it is about 4-6. There are also other classes such as ground, vegetation as the results of classification. It should be noted that laser points can be reflected from the walls of the buildings. When being considered all of X, Y, and Z coordinates, those points can cause the ambiguity between classes. Furthermore, to prepare for further analysis of distribution of elevation and intensity of laser points on the roof of buildings, those points should not be concerned. We mark the overlapped points as a separate class. Following section demonstrate the results of classification the LiDAR data acquired over Roppongi, Tokyo, Japan.

CLASSIFICATION OF LiDAR DATA OF ROPPONGI, TOKYO

A LiDAR data set acquired over Roppongi, Tokyo, Japan was chosen for the testing. DSM, DTM and DHM, which are all in 1-meter grid format, are presented in Figure 2. The classification using non-linear scale space analysis produced the classified buildings as in Figure 3. Finally, laser points were classified into 6 classes according to their heights and sizes. Elevation distribution of each class is demonstrated in Figure 4a and its intensity distribution is demonstrated in Figure 4b. Intensity distribution shows the discrimination between 6 classes in very low (about 10 meter) and very high (about 40 meter) parts of the height scale. It implies the possibility to incorporate pulse intensity in classification of the roof material.

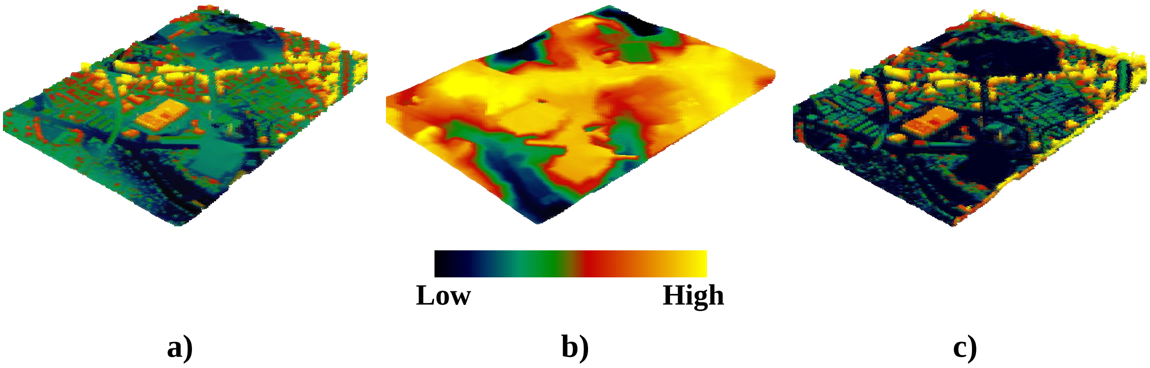


Figure 2. Test area: a) DSM, b) DTM and c) DHM.

Currently, field visit has been carried out to find the relationship between pulse intensity and building types. Incorporating pulse intensity and spectral information in classification will be the next step of our development. The relationship between building usages types and building sizes is also currently investigated.

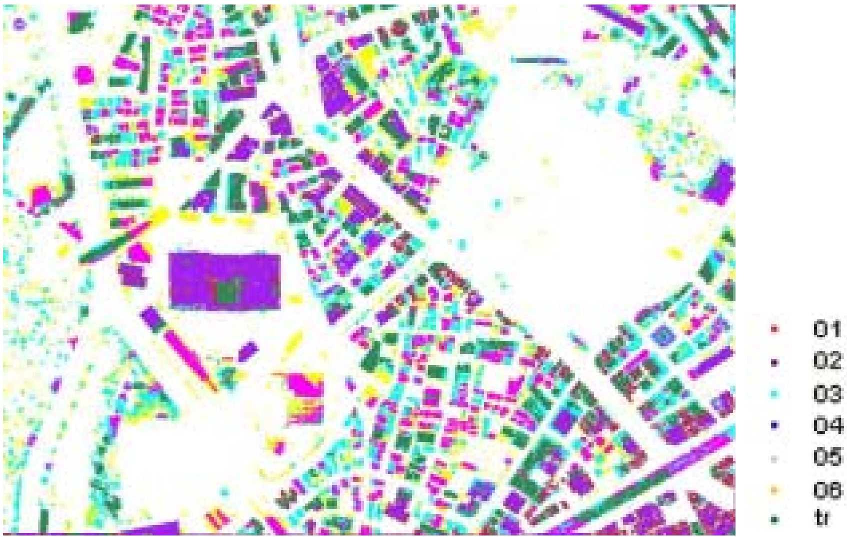
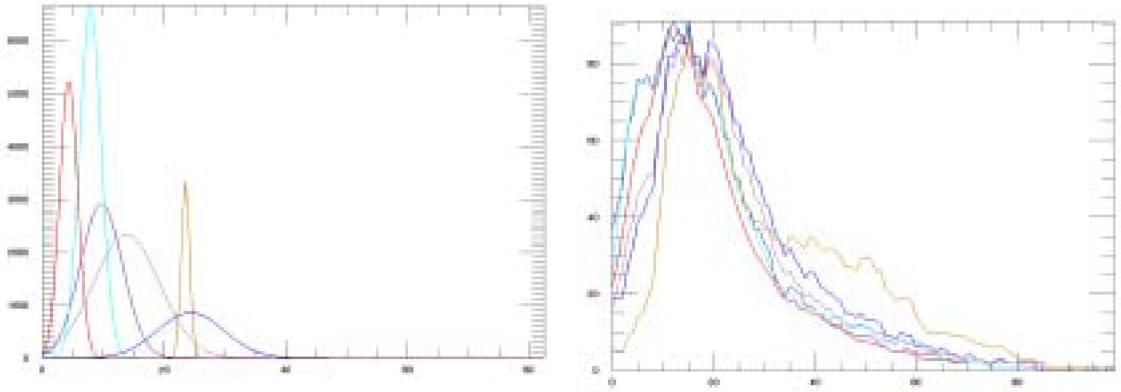


Figure 3. Results of non-linear scale space analysis



a) **b)**

Figure 4. a) Elevation distribution and b) Intensity distribution.

CONCLUSION

Employing LiDAR as primary data in the processing could increase the level of automation. It is promising to speed up the processing and produce higher reliable results. Key factor is the availability of LiDAR data but we propose a flexible mechanism to choose among the available data sets. Change detection between two LiDAR surveying flights infers the possibility to apply for damage detection. In addition, non-linear scale space processing is also proposed and successfully implemented. For classification, we have focused only sizes and heights of buildings but it has been well-prepared and opened to integrate elevation and intensity distribution in further studies.

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