LIDAR FOR UPDATING BUILDING DATABASE

Tuong Thuy Vu, Masashi Matsuoka, Fumio Yamazaki

ABSTRACT: This study is aimed to employ LIDAR (Light Detection and Ranging), a technique that quickly provides precise X, Y, and Z coordinates of earth's surface, in updating height information for current building database. Providing high density laser points, LIDAR is also suitable to detect the changes of buildings in dense urban areas. To achieve the objective, an automatic processing framework is proposed and implemented. Consequently, the capability of LIDAR is demonstrated through testing the implemented framework in a rapidly changed and dense urban area of Tokyo, Japan. The study also states some promising researches to carry out in further studies.

KEYWORDS: LIDAR, height information, building inventory.

1. INTRODUCTION

Remotely sensed technique has been realized as an efficient technique and widely applied in gathering geo-information required for disaster mitigation. Quickly providing geo-information with wide coverage is the advantage of remotely sensed technique. The fast development of this technique has given more and better options for the users such as higher spatial resolution, better radiometric characteristic, more aspects and properties of objects overlying earth's surface. In the context of remotely sensed data for disaster mitigation, damage detection and building inventory are the focuses of interest. While remotely sensed data has been much explored in damage detection (Casciati et al, 1997; Hasegawa et al, 1999; Matsuoka and Yamazaki, 1999), it has not been seriously considered in updating current building inventory database. Rapid changes in dense urban areas demand quicker and more frequent update rather than the update through documents every several years, e.g. five years in Japan. Among the current remotely sensed techniques, which to be chosen as the acquisition technique for updating is the question. Radar or optical, satellite-based or airborne-based imagery, each of them suffers by different drawbacks. Recently, LIDAR has become a preferred technique for rapid topographic mapping. Providing a dense cloud point with X, Y, and Z coordinates, LIDAR could be mentioned as the best candidate. LIDAR data could avoid the shadow problem of optical sensors and the layover problem of radar sensors, which are very severe in dense urban areas. No texture information is a limitation of LIDAR. However, it is improving in very near future LIDAR systems. The reflectance of pulse hit will be recorded and the surveying flight is also equipped with a CCD camera on the same platform. The following section is to briefly describe LIDAR technique and its employment in extraction of building features.

2. LIDAR AND BUILDING EXTRACTION

The basic components of an LIDAR system are the laser scanner, the Global Positioning

System (GPS) receiver and an Inertial Navigation System (INS) (Figure 1). Mounted in a platform like helicopter or aircraft, LIDAR system utilizes opto-mechanical scanning assemblies to emit infrared laser pulses at a high frequency and then records the difference in time between the emission of the laser pulses and the reception of the reflected signals. As a result, a surveying flight could quickly collect a cloud point with X, Y, and Z coordinates. As soon as being adopted, LIDAR becomes the most suitable technique for gathering the third dimension of geo-information in dense urban areas. The very high density of acquired laser point allows detecting not only height but also structure of building features in urban areas.

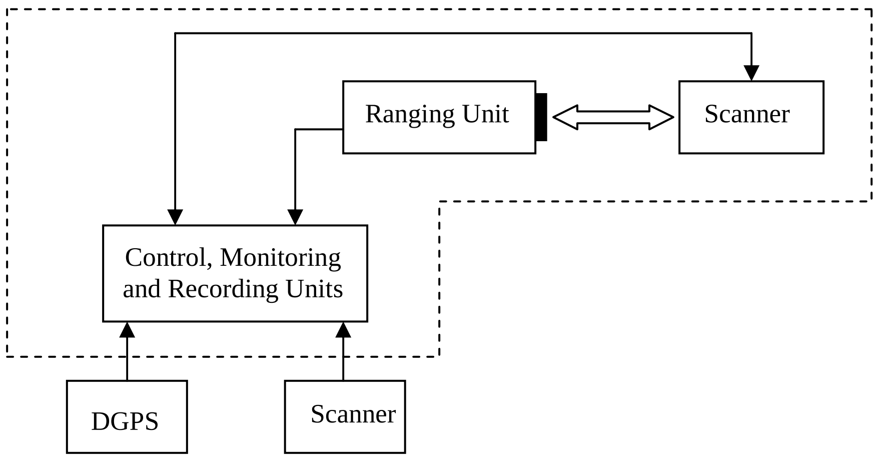


Figure 1. Diagram of a LIDAR System (Wehr and Lohr, 1999)

Building extraction or reconstruction has been the main objective of LIDAR processing. Haala and Brenner (1999) extracted building features through the combination between LIDAR and the aerial photograph. The availability of two-dimensional vector data could assist the reconstruction of building features from LIDAR. The footprint shown in vector data was employed as the guidance for the reconstruction (Vosselman and Dijkman, 2001). Therefore, the processing could be much simplified. Another trend of research is to reconstruct building features from only LIDAR data (Maas and Vosselman, 1999) by searching the planar faces or fitting into a parametric model of building. In this case, LIDAR data should be acquired with very high density like 5-7 points/m^2 to catch the details on the roofs of buildings as well as to distinguish the trees from the buildings. However, building extraction from only LIDAR data like abovementioned methods seem to be unfeasible for Asian cities, which consist of diverse types of buildings such as Tokyo, Bangkok, Shanghai, etc. In this study, the employment of two-dimensional vector data is twofold. Firstly, it is used to simplify the processing LIDAR data. Secondly, it is the object to be updated. Therefore, a well-organized framework of processing should be implemented to switch the role of this vector data and all happened cases should be taken into account. The next section describes in details the proposed framework of processing. It is followed by the results of testing in a study area. The last section summaries the study and points out the further studies of LIDAR in disaster mitigation.

3. METHODOLOGY

The processing is divided into four general modules. These are preprocessing, raster-based processing, vector-based processing and database input as described in the following sub-sections. Except the first module which is an interactive processing, the rest ones are proposed and implemented as the automatic processing.

3.1 Preprocessing

LIDAR and vector data, which is obtained from current building inventory database, are the input data for processing. Generally, LIDAR can be either in irregularly distributed point format or grid format. To prepare for the next raster-based processing, LIDAR points should be interpolated into a grid. Nearest neighbor interpolation is preferred to maintain the sharp leap in elevation along the edges of buildings. The cell size is decided based on the density of laser points. Another step of preprocessing is to derive the bare earth surface, which is usually named Digital Terrain Model (DTM) to distinguish from the original acquired surface from LIDAR, i.e. Digital Surface Model (DSM). Filtering or classification of laser points has been named for this processing (Kraus and Pfeifer, 2001). In this study, it is referred to *ALSwave* method (Vu et al, 2003). The vector data is also prepared for raster-based processing by being rasterized. The preprocessing is also to check and correct the possible systematic shifting between two data sets. This discrepancy might occur during the interpretation, compilation and edition of vector data.

3.2 Raster-based processing

Prior to the processing, it is noted that map generalization, editing error, interpolation effect, reflectance of laser hit from the lower objects nearby the buildings generate the random discrepancies between two data sets. These discrepancies could be eliminated by mathematical morphology filters such as dilation, opening (Weidner and Forstner, 1995). The flowchart of raster processing is shown in Figure 2. The outputs are named *demolished, unchanged*, and *new* to be corresponded to demolished buildings, unchanged buildings and new constructed buildings, respectively.

The intersected part between two data sets shows either demolished buildings or unchanged buildings. Differed from DTM, this intersected part represents the height of the buildings from the footprint to the top. Therefore, it is able to distinguish demolished buildings from the unchanged ones by elevation thresholding. Alternatively, the difference between those two data sets probably represents the new constructed buildings. To eliminate the abovementioned discrepancies, dilation operation is applied on rasterized vector data prior to the differing operation. The next question is that the represented elevation blobs might be caused by the trees in urban areas, which should be removed. A vegetation mask generated from aerial photograph is employed for this removal. Similarly as detecting demolished buildings, DTM is employed here again for differing and thresholding. The last step of processing is applying opening operation to remove the small size blobs created during the processing to detect demolished and new constructed buildings. Summary, raster-based processing creates three following laser point sets, which are distributed in regular grid, for the next vector-based processing.

- Laser points falling into the footprint of unchanged buildings,
- Laser points falling into the mask of demolished buildings, and
- The laser points representing new constructed buildings.

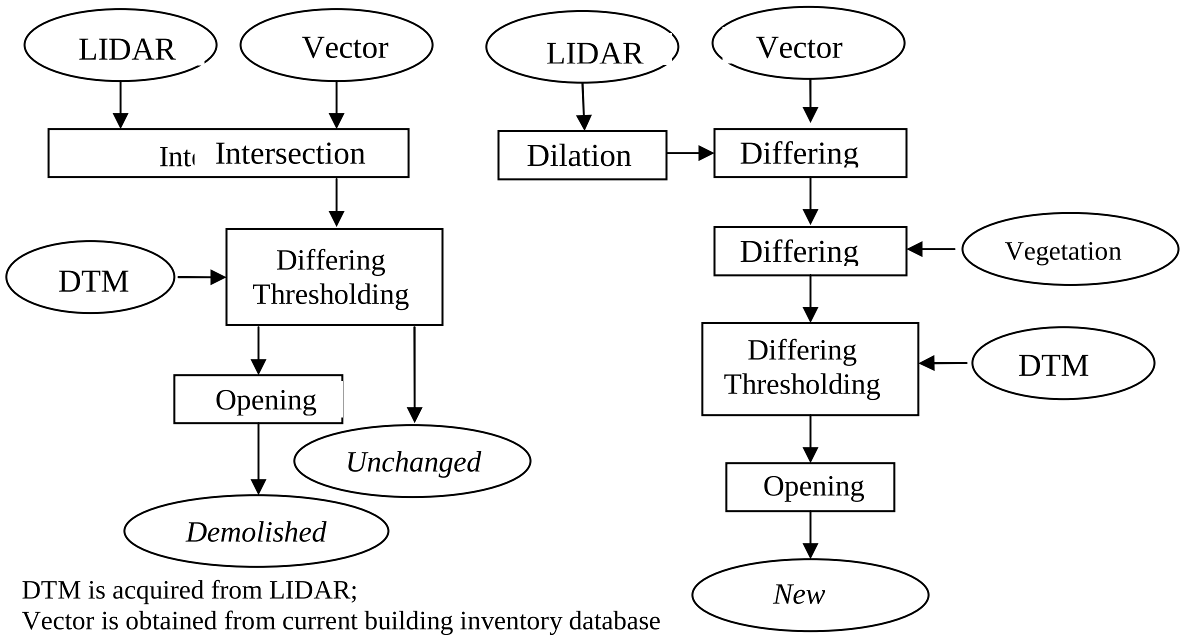


Figure 2. Flowchart of raster-based processing

3.3 Vector-based processing

While raster-based processing operates on pixel-by-pixel, the vector-based processing treats the objects as point, line, and polygon entities. Firstly, *demolished* and *new* laser point sets are converted to polygons by buffer operation. Generated from the automatic raster-based processing and buffer operation, the boundaries of new building polygons and demolished buildings polygons are formed by myriad of vertices, many of which are unnecessary. Let define segment as the straight line connecting two vertices. The angle formed by two adjacent segments is calculated. Ranging from 0 to 180 degree, the angle which is larger than a threshold implies that the vertex at this angle is meaningless. Let define there available polygon layers to be *demolishpoly*, *newpoly* and *unchangedpoly*, which is the current building vector data.

The last step of vector-based processing is verification of the detected demolished and new buildings. Those detected polygons might show the overlap with unchanged polygons. The situation can be listed as new building built in an area which was a part of old building (situation 1), demolished polygons represents a whole demolished building (situation 2a), or a part demolished building (situation 2b), or error due to raster processing (situation 2c).

3.3.1. Verification of situation 1

In this situation, an old building which was demolished for the construction of new building remains as unchanged building after raster-based processing. It is because of the LIDAR reflection from the new one. In vector format, its polygon overlaps with polygon in *newpoly*. Therefore, for each overlapped polygon in *newpoly*, the connection between a pair of vertices will cut the overlapping polygon in *unchangedpoly*. This is the criteria to remove such a demolished building in situation 1.

3.3.2. Verification of situation 2

Due to the discrepancies between two input data sets which could not be completely eliminated in raster-processing, there might be several meaningless polygons in *demolishedpoly*. Firstly, each polygon belonging to *demolishedpoly* is checked whether it contains the center of any polygon of *unchangedpoly*. Secondly, the areas of a pair overlapping polygons from these two layers are compared. The discrimination in situation 2 can be shown in Table 1.

Table 1. Discrimination in situation 2 based on polygons in *demolishedpoly*

Situation	*Contain unchanged's center*	*Area*
2a	Yes	Greater than **threshold**
2b	Yes	Less than **threshold**
2c	No	Less than **threshold**

(**threshold** is made as percentage of unchanged polygon)

After finishing all verifications, different labels are assigned for each type of buildings such as new buildings, unchanged buildings and demolished buildings.

3.4 Database input

The average Z value of all laser points which fall into each above detected polygons is assigned to be height attribute of the buildings, except value of 0 is assigned for demolished buildings. The building database has been updated with detected new buildings, demolished buildings and added with real height.

4. TEST RESULTS

An area in Shinjuku, Tokyo, Japan was chosen for the test of implemented framework. This area is typified by different types and very high density of buildings. DSM acquired from LIDAR, which provided by Asia Air Survey Co. Ltd., Shinjuku-ku, Japan, can be shown in perspective view in Figure 3. Figure 4 presents the footprint of building features which is already in building database. There were 990 buildings recorded in current database. Following the described processing framework in Section 2, 20 demolished buildings and 29 new buildings were detected. The height of building was added as a new attribute in building database (Figure 5). Figure 5 also shows a simple perspective view of this building database. Figure 6 illustrates the layout of detected results in two dimensions.

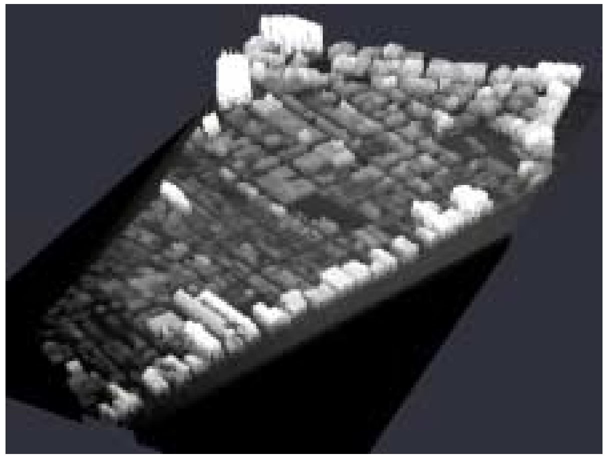
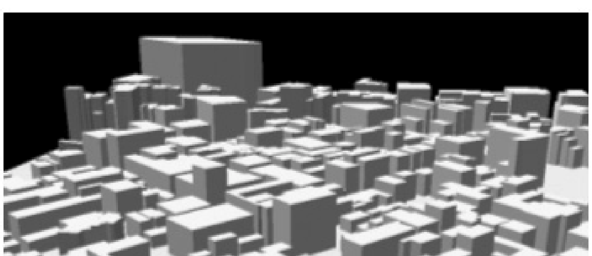


Figure 3. DSM acquired from LIDAR over study area

Figure 4. Footprints from current building database



Attributes of Building.shp

Shape	Area	Perimeter	Kv_	Kv_id	Kvi3	Kvi4	Kvi5	Kvi6	Kvi7	Kvi8	Label	Z
Polygon	3186.320	249.970	0	1	16	0	11	121	0	1	1	59.79242
Polygon	811.349	133.441	0	2	8	0	11	121	0	1	1	30.83906
Polygon	70.041	37.893	0	3	2	0	11	123	0	1	1	5.839156
Polygon	70.952	38.269	0	4	5	0	11	121	0	1	1	15.40076
Polygon	55.550	34.554	0	6	4	0	11	123	0	1	1	12.85962
Polygon	59.629	31.865	0	7	6	0	11	121	0	1	1	21.13797
Polygon	134.743	47.252	0	8	11	1	11	121	0	3	1	29.38500
Polygon	52.758	30.315	0	9	2	0	21	123	0	1	1	14.80905

Figure 5. Updated database

Figure 6. Detected results

4. CONCLUSION

The study focused in designing and implementing an automatic processing to update building database from LIDAR data. A small test area was employed for demonstrative purpose. It showed the capability of LIDAR in providing the required information in three dimensions. Moreover, it is also useful in detection of the changes in a very dense urban area. The recently implemented processing system is going to employ for other study areas and a mechanism for accuracy assessment will be implemented. Processing time for different test areas should be recorded and reported to prove the efficiency of quick update by this method. Integrating texture information from aerial photograph or high-resolution satellite imagery in processing LIDAR is also the promising research in employment of remotely sensed data for disaster mitigation.

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