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Scopus Compendex and Geobase Elsevier,
Geo-Ref Information Services-USA, List B of Scientific
Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 09, No. 01

February 2016, P.P.162-166

3D Reconstruction of Buildings from Classified LiDAR Point Cloud

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Abstract: 3D reconstruction of buildings from LiDAR point cloud is the creation of three dimensional building models from LiDAR point cloud. The aim of this study was to reconstruct 3d building models from LiDAR point cloud. Three datasets, each with different point densities were used and micro-station software was utilized for 3d reconstruction in this study. Two approaches were adopted for the purpose of reconstruction methodology that is automatic and half automatic approach. These two approaches were conducted for the three different datasets and their results were analyzed. Different tools that can be used for the editing of models were analyzed and changes occurred by varying different parameters were also noted. The data set with higher point density gave a very good model in automatic approach without much manual interventions, but as the point density decreased automatic method was not feasible. As a result half automatic method was implemented and more manual effort during this approach gave better results. This study proved that 3D reconstruction of buildings from LiDAR point cloud can be easily done using micro-station if the density of the point cloud is higher but for LiDAR datasets with less number of points lot of manual work is essential and also additional data like orthophotos are essential for the proper reconstruction of buildings.

Keywords: *Microstation, Terrasolid, LiDAR, Vectorization, Remote Sensing*

1. Introduction

LiDAR (Light Detection and Ranging) is a technology for measuring positions of physical objects, rapidly. LiDAR uses a laser beam to measure the distance from an object to the scanner, and a mechanical-optical mount to scan the laser across a scene accurately. LiDAR can collect tens of thousands to over a million positions per second. Laser scanning has achieved great prominence within the civil engineering community in recent years for topics as divergent as coastline monitoring (Olsen et al. 2009), airport layout optimization (Parrish and Nowak 2009), and ground-displacement identification for water-system risk assessment (Stewart,2009). Airborne LiDAR is capable of providing highly accurate measurements of vertical features with single pulse, multiple pulses, or full waveform. LiDAR technology is being progressively more practiced in ecology, forestry, geomorphology, seismology, environmental research and remote sensing because of its capability to produce three-dimensional (3D) point data with high spatial resolution and accuracy (Gaveau and Hill, 2003). The technological development in the fields of computer vision and digital photogrammetry provides new tools and automated solutions for applications in urban studies, cadastre, etc, associated with urban development, identification of illegal constructions, 3D modelling, change detection, etc. The emergence of LIDAR technology makes quickly extract building features possible. As a kind of initiative remote sensor system, Airborne LIDAR system can fast gain three dimensional data with high accuracy, and has the superiority of lower sensitivity to the environment.

Regardless of the type of LiDAR used, the combination of direction and distance is used to create a cloud of measured points located relative to the scanner. If the actual position and orientation of the scanner in real-world coordinates are known, these can be integrated with the scanner-relative measurements to produce a point cloud in real-world coordinates. Knowing where the LiDAR device is thus key to building data sets that can be integrated with other geographic information and information systems.

Three dimensional building reconstructions has been a highly active research topic for years. There has been an increasing demand in various applications such as urban planning, virtual tourism, computer gaming, real-time emergency response, and robot navigation. Three dimensional reconstructions of buildings can be easily achieved through microstation software.

2. Data Used

Three different datasets from two different locations were used for this study. The main difference in each datasets was the point density. The point densities of the three datasets where entirely different. The datasets having more point density had more clarity and the level of details was high. Dataset with less point density had much lesser details. The point densities of the three datasets are:

Table 1 *Data used*

Dataset	Point Density (/sq m)	No. of points
1	1	4545
2	5	85998
3	62	604374

Three datasets of three different point density where chosen. Datasets having point densities 1/sq m and 5/sq m where from the same area and the dataset having point density 62/sq m was from a different area. Table 1 shows the point density of each datasets and number of points.

3. Methodology

The general methodology for 3d reconstruction from a classified LiDAR point cloud using microstation is:

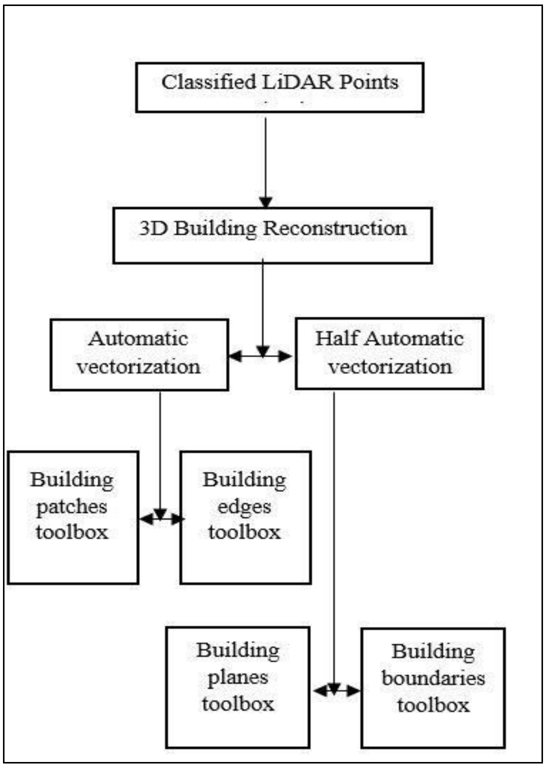

Figure 1 *Methodology flowchart*

The classified LiDAR data in which the buildings and ground points are clearly grouped are used to for 3d reconstruction. This point cloud is imported into the microstation environment using Terrascan. TerraScan is a dedicated software solution for processing laser scanning point clouds. It can easily handle millions of points. Generally we have two approaches for vectorization.

3.1. Automatic Vectorization

TerraScan provides a set of tools for automatic building vectorization based on airborne laser scanning (ALS) data. The 3D vector models are created fully-automatically but for higher accuracy, they can be modified manually with dedicated tools. These tools ensure that the topology of a building model is preserved and allow fast and easy editing. The tools can also be used to create non-planar roof shapes. The automatic vectorization is based on classified laser points of the ground and on building roofs. Building footprints can be used in the vectorization process for placing walls or roof edges. Image data loaded in TerraPhoto supports the automatic vectorization of buildings. For manual editing, images in camera views improve the result essentially, because edges of roofs, roof structures, and smaller details may not be detectable accurately in the laser data. Vectorize Buildings tool creates 3D building models based on loaded laser data. We have to define certain settings during the vectorization process which completely depends on the area and density of the LiDAR point cloud.

After vectorization of the building, the polygons from roof line were constructed using construct roof polygon tool. Then the building model were created from roof polygon using create buildings from polygon tool. Now the building models were automatically created. The resultant model will be a rough one whose accuracy completely depends on the quality and density of the LiDAR data. So, for correcting the model check building model tool was applied which will help to analyse and edit one model at a time. By using these tools effectively and re-computing the building model we will be able to reconstruct perfect building models from the LiDAR point cloud data.

3.2. Half Automatic Vectorization

This method is generally used when the density of LiDAR point cloud is very less. This method is very time consuming and lot of manual work should be done if we are to follow this method. But if the point cloud is less dense then there will be lack of details at different locations, only half automatic method can be used for 3d reconstruction. Construct Planar Building tool from the Draw tool box is used to create a 3D vector model of a building based on laser points on planar surfaces of the roof. With this tool, one building at a time can be vectorized in a half-automatic way.

For each planar part it creates a roof polygon. The roof polygons can be edited by a set of tools provided for building vectorization. After the roof planes are fixed, the final 3D vector model of a building is created by drawing vertical walls for all outer edges of the roof. By using various tools appropriately we can formulate 3d models of building accurately. But this includes lot of manual works and a reference image of the area should be loaded in background of the LiDAR data in order to edit the model perfectly. So additional data rather than the LiDAR data like orthophotos or images of the area are also needed to conduct half automatic vectorization.

The type of method adopted from afore mentioned methods for the specific dataset are:

Table 2 Methodology used

Dataset	Point density(/sq. m)	Methodology used
1	1	Half automatic method
2	5	Automatic and Half automatic method
3	62	Automatic method

Different parameter values should be provided manually for the proper vectorization of the buildings in half automatic method. This can be done through trial and error method. That is provide different values for each parameter and notice the change occurring and then choose the appropriate value. The parameter values differ according to the density of the point cloud and the nature of the dataset.

The values chosen for each parameter in half automatic vectorization method after trial and error procedure are:

Table 3 Parameter values

Parameter	Dataset 2	Dataset 3
Maximum gap (m)	2	3
Planarity tolerance (m)	0.1	0.15
Increase tolerance(m)	0.2	0.2
Minimum area (m^2)	20	40
Minimum detail (m^2)	3	5
Roof slope (degree)	75	75

4. Results and Discussions

The two approaches were conducted on the various datasets and the following results were obtained. Each and every result from the three datasets was compared and analyzed for proper understanding of the changes occurred with the two approaches in the datasets.

4.1 Results from Automatic Approach

The figures 2, 3, 4 and 5 show the results obtained from automatic vectorization method.

These models were obtained very easily and rapidly without any further editing of the model. This was owing to the high point density of the LiDAR data.

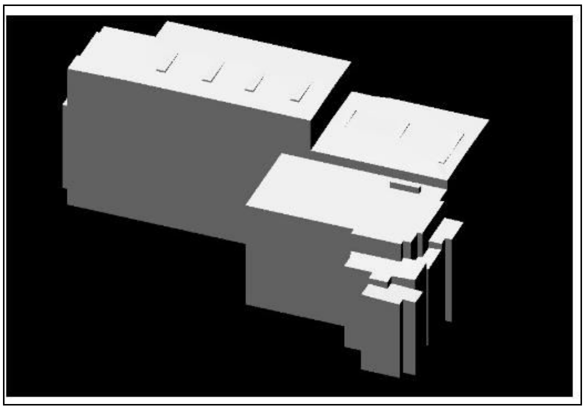

Figure 2 *62points/sq. m LiDAR data*

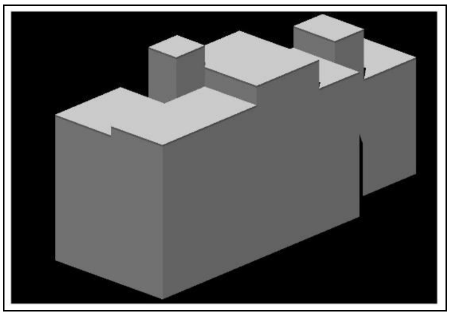

Figure 3 *Building model extracted from 5points/sq. m LiDAR data*

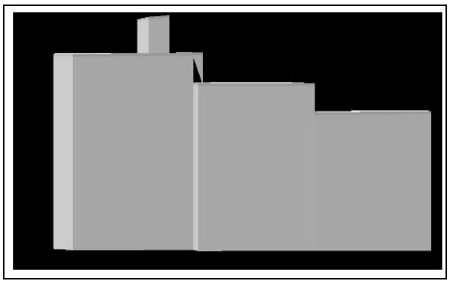

Figure 4 *Building model extracted from 1point/sq. m LiDAR data*

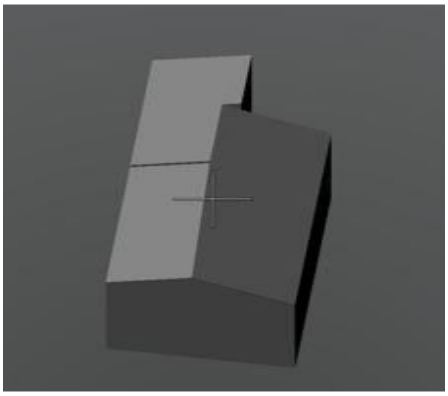

Figure 5 *Building model extracted from 1point/sq. m LiDAR data*

4.2 Results from Half Automatic Approach

The figures 6, 7, 8 and 9show the results obtained from half automatic vectorization method.

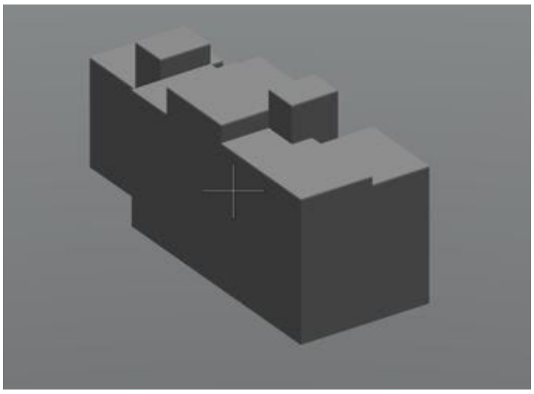

Figure 6 *Building model extracted from 1point/sq. m LiDAR data*

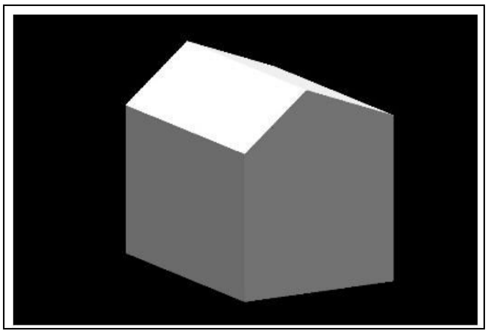

Figure 7 *Building model extracted from 1point/sq. m LiDAR data*

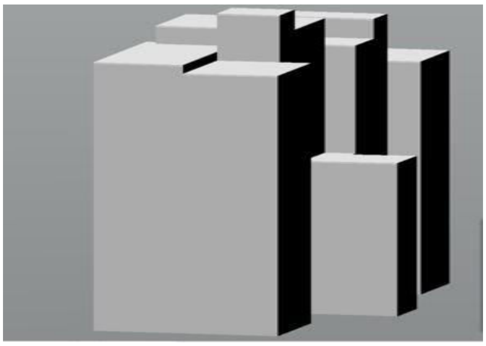

Figure 8 *Building model extracted from 1point/sq. m LiDAR data*

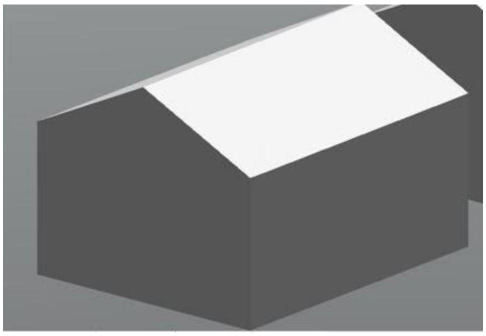

Figure 9 *Building model extracted from 5point/sq. m LiDAR data*

4.3. Discussions

By using microstation, 3d reconstruction of the buildings from the LiDAR point cloud was achieved. But the mode of approach should be decided based upon the density of the point cloud. By observing the results obtained it can be generalized as:

- Low density < 2 points / m² gives good models of large buildings but more problems with small buildings, loss of small details and roof structures
- Medium density 2-10 points/ m² gives good models
- High density > 10 points / m² gives accurate models with details and roof structures

During automatic vectorization approach, by changing the values of various parameters we can achieve perfect 3d models. The parameters should be given according to the area of consideration. That is:

1) By changing the planarity tolerance we can distinguish each and every planes separately. If the planes are closer to each other we have to decrease the planarity tolerance value otherwise both the planes will merge as one.
2) Maximum area and minimum detail completely depends on the building area and size which can be directly measured from microstation by creating a fence and measuring the area. So additional details or data are not required for this purpose.
3) By increasing the maximum gap we can distinguish the closely spaced buildings that are two separate models will be created. Otherwise if we decrease the maximum gap two closely spaced buildings will merge as one and a single model will be created.

After creation of the model, the check building model tool allows us to check and make changes to each and every building model one at a time. By using the recompute option we can change the parameters and see how the model appears. So a trial and error approach can also be done in order to achieve a picture perfect model. Building patches and building edges toolboxes must be used appropriately for the correction of models if needed.

But through automatic method if the point cloud density is very low then formation of models having sloping roofs will be very difficult as the roof details will not be available clearly in LiDAR data. So for sloping roofs half automatic method will be good for achieving a perfect model. By implementing half automatic method we can manually identify the planar details and edges and also give details wherever there is missing of details.

Although half automatic building vectorization approach requires a lot of manual interaction, it has some advantages compared with the automatic approach. There are a few tools which allow the creation of roof planes without the availability of laser data. These tools can derive the plane equation from other sources than laser data and thus, enable the creation of building models in cases of missing laser data on roofs. Another disadvantage of automatic approach is that it is impossible to model non-planar roofs or roofs that do not have dominating planar surfaces following a base direction.

In half automatic approach building planes and building edges toolboxes must be used appropriately to find each and every plane and edges and combine them perfectly for the formulation of a perfect model.

5. Conclusions

Three dimensional reconstructions of buildings from LiDAR data can be easily achieved through microstation software, provided that the point cloud should be dense enough and contains all small details. If density is less or there is lack of details then half automatic method should be implemented. But the problem of half automatic method is that lot of manual work should be put into it and it is time consuming also. Whereas if the data is dense enough then automatic method can be implemented which is too easy and fast.

LiDAR solutions has gained a vast momentum now a days. So more research and work should be carried out in this area for attaining fast and accurate reconstruction of buildings from LiDAR point cloud.

6. Acknowledgements

The authors like to thank Indian Institute of Space Science and Technology, Trivandrum, India, for providing the lab facilities and peaceful working environment for the completion of this work.

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