COMPARISON OF AUTOMATIC FEATURE EXTRACTION METHODS FOR BUILDING ROOF PLANES BY USING AIRBORNE LIDAR DATA AND HIGH RESOLUTION SATELLITE IMAGE

Muhammed Enes Atik, Şaziye Özge Dönmez, Zaide Duran, Cengizhan İpbüker

Muhammed Enes ATİK
Research Assistant;
Department of Geomatics Engineering,
Istanbul Technical University, 34469-Maslak, Istanbul, Turkey;
atikm@itu.edu.tr;

Şaziye Özge DÖNMEZ
Research Assistant;
Department of Geomatics Engineering,
Istanbul Technical University, 34469-Maslak, Istanbul, Turkey;
donmezsaz@itu.edu.tr;

Zaide DURAN
Associate Professor;
Department of Geomatics Engineering,
Istanbul Technical University, 34469-Maslak, Istanbul, Turkey;
duranza@itu.edu.tr

Cengizhan İPBÜKER
Professor;
Department of Geomatics Engineering,
Istanbul Technical University, 34469-Maslak, Istanbul, Turkey;
buker@itu.edu.tr

Abstract
Airborne LIDAR technology is one of the most widely used rapid solutions for producing 3D dense point cloud. Also, automatic feature extraction is under 3D Modelling studies in Geographic Information Systems (GIS). There are several techniques for reconstruction and classification in this field. RANSAC (RANdom SAMple Consensus) is one of the data processing method in order to use LIDAR data. Additionally, another technique for feature extraction is object based point cloud analysis. In this paper, RANSAC are used for feature extraction on 3D Airborne LIDAR data. The study area is selected in Turkey. Roof planes are detected by using both methods. A code is written on MATLAB software for RANSAC algorithm. eCognition software is used for object based point cloud analysis. In this analysis, very high resolution satellite images are combined with 3D point cloud of the study area. In the result of the study, the roof geometry that is obtained using both methods are compared scientifically in terms of area and number of points. In the conclusion step, the results are discussed and future works are planned.

Keywords: 3D Point Cloud Processing, Object-Based Image Analysis, Feature Extraction

INTRODUCTION

In 21th century, preserving natural sources in long-term, sustainability applications and environmental monitoring have crucial importance for all around the world. In this manner, solar energy applications, planning urbanization
professionally are also some of the common sights. In crowded cities, planning the new urban areas is one of the main topics of decision-makers, and planners. Developing technology has many advantages for also monitoring urbanization in urban and rural areas also. Automatic roof detection methods are spreading around with using effective techniques in order to detect and monitor the buildings of urban areas. Identifying natural or man-made changes is possible with Remote Sensing (RS). Remotely sensed data is widely used for rapid solutions as monitoring the Earth surface. Feature extraction techniques are widely used for observing and analysing special objects. Land cover and land use classes are used for regional and global monitoring. Land use and land cover classification is produced and updated in many organisations rapidly. New technological developments facilitated for economical and high accurate solutions for these processing and analysis. Besides very high resolution images, Airborne LIDAR technology utilize many advantages for semi-automatic extraction process. In the study, it is aimed to detect roofs with using separate algorithms for analysing effectiveness of the remote sensing technologies as well. Also, different algorithms performances are tested for interpretation and testing before conducting extended areas. In this study, automatic roof detection is conducted as different methods. Very high resolution satellite image and point cloud are used for the application. In selected test area, total areas of the roofs are calculated and showed in the tables. As result, roof areas are calculated separately in the end of the study with two different methods. The results are shown in the tables, for interpretation and visualized as figures. Several advantage /disadvantages are discussed in the end of the study.

RELATED WORKS

Researchers from photogrammetry and computer vision disciplines have interested in studies on building detection. Some researchers used image data only, while some used only LIDAR, others built a two-way integration (Demir, 2015).

Forlani et al. (2005) apply RANSAC algorithm to detect building roof planes automatically using a partition in 8 classes of the gradient orientation. In this study, raw LIDAR is classified as buildings, terrain and vegetation. The classification results have been verified with digital large-scale maps, in 1:5 000 scaled aerial images and by laying the colour-coded DSM upon the classification raster image. But comparison between LIDAR and raster data is not aimed.

Sohn and Dowman (2007) suggest a hybrid method for automatic building extraction. Their method include combination of IKONOS images and low-resolution LIDAR data. Firstly, building cluster was defined using height attribute of laser data. And, IKONOS image was classified using Normalized Difference Vegetation Index (NDVI) to detect building edges. Building edges that obtained from two data (collected by either data-driven or model-driven manner) are integrated in order to eliminate the weakness of both methods. This method has a detection percentage of 90.1% (the correctness) and the overall quality of 80.5%.

Kurdi et. al. (2008) represent an extended version of RANSAC algorithm for detecting building roof planes from point cloud. Fundamentally, they add two new improvements to RANSAC algorithm. First, a standard deviation condition is accepted to decrease the negative influence of the distance tolerance threshold t. Second, mathematical morphology procedures on the binary Digital Surface Model (DSMb) calculated for removing noisy points and lost points on LIDAR data.

Kim and Habib (2009) integrate photogrammetric and LIDAR data to extract complex building roof planes. Building roof planes hypothesis is generated for LIDAR data and detected primitive boundaries of roofs. These primitive boundaries are refined with integration of photogrammetric and LIDAR data. The correctness and completeness values and ratios of the study area were 89% and 95%, respectively.

Zhang et al. (2014) proposed primitive-based 3D building roof modelling method. The main idea is representing building roofs by parametric primitives and construct cost functions using information from both LIDAR data and the aerial imagery. 3D building models have average root mean square error of 0.6 m in XY plane and 0.1 m in Z direction in the study case.

The studies focused on application of methods. Although other studies try to integrate methods on LIDAR data and satellite images, in this paper, we compared two different methods. RANSAC is used for detecting planes from LIDAR data. Object based classification is used for detecting planes from high-resolution satellite images.

DATA AND METHODS

Data

In the application as remotely sensed data, Pleiades satellite image and airborne laser scanner (also known as LIDAR) data are used for detecting roof planes and calculating areas of the roofs. Satellite image’s acquisition date is November
the 9th 2014. It is produced in ground control stations after pre-processing steps. The Pleiadas satellite sensors are produced and supported by AIRBUS Defence and Space units. High resolution images are produced and encourages to use for many applications. Also, LIDAR data’s capture date is between September the 13th - November the 7th, 2014. It is captured by Republic of Turkey General Command of Mapping. As satellite image, Pleiades-1A is used for the application. The spatial resolution of Pleiades-1A images are in the range of 0.5 - 2 meter resolution.

METHODS

Random sample consensus (RANSAC)

RANSAC was developed by Fischer and Bolles (1981) and is mostly used for shape detection. Basic concept of RANSAC algorithm differs from traditional object detection method. In traditional method, maximum amount of point is used as input. Then unsuitable points are filtered and data are decreased. But, in RANSAC, minimum number of point, for example three points define a plane, is selected randomly and used as input (Polat and Uysal, 2017). Then, the remaining points are tested in order to match the corresponding shape. The algorithm does not continue until all points have been tested. Instead, the number of “s” that matches a selected, “p” probability value is used to calculate the model, and this selection repeats N times until it is determined as well (Schnabel, 2007). The number of trials N can be calculated using equation (1).

\[
N = \frac{\log(1-\alpha)}{\log(1-(1-\epsilon)^s)}
\]  

In equation (1), s is the minimum number of the points that are needed to define as model shape (for plane s=3). After certain number of iterations, the model that have the largest number of inliers is extracted and the algorithm continues to process remaining data (Li et al., 2017).

In this study, Marco Zuliani’s RANSAC algorithm (Zuliani, 2008) was used. The algorithm is named as MSAC that is RANSAC based algorithm. M-estimator Sample Consensus (MSAC) was implemented by Torr and Zisserman (2000). There is only difference between RANSAC and MSAC is the evaluation of inliers and outliers. In RANSAC, each model is scored with its number of inliers. In MSAC, the score of each inliers is weighted, based on how well it fit the model.

Some advantages of RANSAC algorithm:
- It has basic concept and easily performed.
- It has general paradigm that is used in wide application areas.
- It also works on data with an outlier value of more than 50% (Schnabel, 2007)

In this paper, the algorithm is applied several successive times to detect the whole roof planes. In each iteration, the set of considered points is removed from the original cloud. This operation is repeated until the number of non-modelled points becomes smaller than a given threshold (Kurdi et al., 2008).

Object-Based Image Analysis (OBIA)

RS technologies are commonly used for environmental monitoring. This includes, urbanization, forestry, agricultural monitoring and so on. RS applications are effective for using detecting boundaries, as well. Land administration issues are widely dominated by RS all around the world. Orthomosaics (with using aerial images) and satellite images are proper for edge detection and producing cadastral maps those have boundaries. In those manner, very high resolution and middle resolution images are sparsely preferred for producing land cove and land use maps. Behalf of field surveys for all processes, using RS technologies have many advantages such as being economic, time-saving, and more proper for most of conditions (weather, rapidly producing, updating and so on). Throughout the years, free and middle resolution satellite images are used for image processing. These processing includes classification for producing thematic and topographic maps. Classification methods are several and based on the needed application, as well. With developing technology, resolution of satellite images are improved fast by time. Besides usage of pixel based image analysis, some new perspectives are improved for higher resolution images continuously. Additionally, pixel-based image analysis, object-based image analysis is started to be preferred especially for high-resolution images. In several analysis, pixel-based analysis have some limitations. Segmentation-based classification shows finer results with comparing usual per-pixel methods according to results of the applications (Blaschke, 2001). Pixel-based Object-based image analysis (OBIA) includes, segmentation, and object-based classification processes as differently. Segmentation step is required for grouping related pixels. Image segmentation advises extracting segments as spatial and spectrally
grouped pixels according to geometrical, topological and/or textural characteristics (Schöpfer et al., 2010). Moreover, based on the application segmentation parameters are changed by the specialist of OBIA.

APPLICATION

RANSAC algorithm and object-based classification were applied to LIDAR data and satellite image, respectively. It is aimed to detect roof plane surface and compare both methods aspects for calculating surface areas (Equation 2).

\[
Correctness \, (\%) = 100 - \frac{\text{Detected Area} - \text{Reference Area}}{\text{Reference Area}}
\]  

(2)

In this study, Bergama, Turkey is chosen as study area. Aerial LIDAR data and high-resolution satellite image were used for comparison. LIDAR data was produced by Republic of Turkey General Command of Mapping. The data was collected between September, the 13th and November, the 7th 2014 in Bergama. Cloud density is 2 point/m² (Kayi et al., 2015). A prison area was selected as application area. There are 10 roof planes in the site area.

RANSAC algorithm is performed using MATLAB software. At first, the point cloud was cut as a height threshold for obtaining ground plane of the area. Thus, every remaining point in the cloud was accepted as a point of the plain. 8 of 10 planes were detected. In each iteration largest plane was detected in the algorithm. Then, the plane that is founded was deleted for the next iteration for finding other planes.

The selected area of satellite image is shown as Figure 1 below. Satellite image of Bergama is obtained as 2 meter spatial resolution of panchromatic band and 0.5 meter spatial resolution of multispectral bands. These are used for pansharpening process. In the end of the process, 0.5 meter spatial resolution image is produced. Throughout the years, pixel-based image classification is performed for many kind of applications. However, OBIA has some advantages in several aspects, especially for very-high resolution images. In the application, segmentation is performed for indicating easily automated odds and time-saving contribution to the study. Thus, OBIA side of the study focuses on segmentation of remotely sensed image. eCognition software is used for performing image segmentation. Objects are produces from
segmentation for roof of the buildings. The objects are shown as in Figure 2 below. The selected roof of the areas are shown as red segments. After determining of the segmentation parameters, the roof areas of the buildings are calculated the total amount of the pixel numbers for each segments. Roofs are able to determined mostly as one segment -only one of them is two segment groups.

Figure 3. Selected Area in Bergama District

Figure 4. Image segmentation of prison area buildings
RESULTS AND DISCUSSION

As a result, the area of each plane was calculated. Reference area values were calculated as manually using high resolution satellite image. LIDAR data resolution was not enough to draw planes. The planes are compared according to their area values. But, the planes have some curvature. Because of this, planes detected by RANSAC were projected. Thus, comparison of the areas would be more proper. The result of comparison is given table 1.

<table>
<thead>
<tr>
<th>PLANES</th>
<th>RANSAC (m²)</th>
<th>OBJECT-BASED (m²)</th>
<th>REFERENCE (m²)</th>
<th>Ratio of Correctness (RANSAC)</th>
<th>Ratio of Correctness (Object-Based)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLANE 1</td>
<td>277.83</td>
<td>261.75</td>
<td>274.98</td>
<td>98.96</td>
<td>95.19</td>
</tr>
<tr>
<td>PLANE 2</td>
<td>314.65</td>
<td>286.5</td>
<td>312.06</td>
<td>99.17</td>
<td>91.81</td>
</tr>
<tr>
<td>PLANE 3</td>
<td>249.91</td>
<td>249</td>
<td>259.31</td>
<td>96.37</td>
<td>96.02</td>
</tr>
<tr>
<td>PLANE 4</td>
<td>286.17</td>
<td>270.75</td>
<td>294.28</td>
<td>97.24</td>
<td>92.00</td>
</tr>
<tr>
<td>PLANE 5</td>
<td>157</td>
<td>169.25</td>
<td>166.63</td>
<td>94.22</td>
<td>98.43</td>
</tr>
<tr>
<td>PLANE 6</td>
<td>166.92</td>
<td>169.25</td>
<td>167.05</td>
<td>99.92</td>
<td>98.68</td>
</tr>
<tr>
<td>PLANE 7</td>
<td>137.71</td>
<td>163</td>
<td>184.85</td>
<td>74.50</td>
<td>88.18</td>
</tr>
<tr>
<td>PLANE 8</td>
<td>-</td>
<td>144.25</td>
<td>140.75</td>
<td>-</td>
<td>97.51</td>
</tr>
<tr>
<td>PLANE 9</td>
<td>147.73</td>
<td>115.25</td>
<td>175.31</td>
<td>84.27</td>
<td>65.74</td>
</tr>
<tr>
<td>PLANE 10</td>
<td>-</td>
<td>122.25</td>
<td>115.61</td>
<td>-</td>
<td>94.26</td>
</tr>
</tbody>
</table>

Some planes are not detected using 3D RANSAC. Because some points in point cloud are not available for initial model parameters in 3D RANSAC. All planes were detected using object-based classification. The sunlight affects the satellite images. Shadows in the image could be detected as roof plane by object-based classification. LIDAR is not affected by the sunlight. 3D RANSAC algorithm have more completeness than object-based classification.

Resolution of both LIDAR and satellite image can affect methods performances. The application can be made on datas that have high resolution from data used in this study. Thus, the algorithm can be applied on more flat planes. Also, the study area could be larger.

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BIOGRAPHY

Muhammed Enes Atik is a MSc student and a research assistant in the Geomatics Engineering Department, Istanbul Technical University (ITU). His main research interests are exploration of Photogrammetry, Image and Point Cloud Processing and 3D Modelling.

Şaziye Özge Dönmez is a PhD student and a research assistant in the Geomatics Engineering Department, Istanbul Technical University (ITU). She has a master degree in Geomatics Engineering from (ITU). Her main research interests are exploration of Geographical Information Systems (GIS), Cartography and optical Remote Sensing (RS) applications.

Zaide Duran is a Associate Professor of Geomatics Engineering Department of Istanbul Technical University. She has many international and national scientific publication about Photogrammetry, Laser Scanning, 3D Modelling and Geographic Information Systems.

Cengizhan İpbüker is a Professor of Geomatics Engineering Department of Istanbul Technical University. He has many has many international and national scientific publication about Map Projections, Geographic Information Systems, Remote Sensing and Cartography.