

# BUILDING EXTRACTION FROM LASER SCANNING DATA

F. Karsli<sup>a,\*</sup>, O. Kahya<sup>a</sup>

<sup>a</sup> KTU, Dept. of Geodesy and Photogrammetry Engineering, 61080 Trabzon, Turkey –  
(fkarsli, okahya)@ktu.edu.tr

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## ABSTRACT:

Laser scanning systems are frequently used to provide the digital surface models, DSM, of the earth surface. Laser scanning is a fast and precise technique to extract information related with various objects (terrain and non-terrain). Automatic extraction of objects from laser scanner data and images has recently been an important subject. Buildings are the objects of the highest interest in 3D city modeling. Urban areas are rapidly changing due to human activities in construction, destruction or extension of topographic elements such as buildings and roads. This mandates the availability of fast data acquisition technique and automatic method for detecting and extracting 3D topographic objects from the data. In this paper, building details were extracted from laser scanning data. We used data which were produced by ISPRS III commission to be evaluated the filtering techniques belonging to Stuttgart city center. We produced an efficient algorithm with Hough transform technique by using MATLAB software. We present a sequential Hough transform for detection of building in point clouds. Our algorithm consists of two sequential steps of low dimensional Hough transforms. The first step, called *Orientation Estimation*, uses the Gaussian sphere of the input data and performs a 2D Hough Transform for finding strong hypotheses for the direction of building axis. The second step of *Position and Radius Estimation* consists of a 3D Hough transform for estimating building position and radius. This sequential breakdown reduces the space and time complexity while retaining the advantages of robustness against outliers and multiple instances. The results of applying this algorithm to real data sets from two industrial sites are presented that demonstrate the effectiveness of this procedure for building detection.

## 1. INTRODUCTION

Recent advances in 3D scanning technologies have made possible high-speed acquisition of dense and accurate point clouds at moderate costs (Laser scanner survey, 2005). The explicit geometric information available from point clouds can be used to automate the 3D reconstruction process, which has been largely manual till now. This is especially true for the reconstruction of industrial sites as due to their man-made origin presence of well-defined CAD primitives can be expected. As-built modeling of industrial sites is required for documentation and for various emerging technologies that use Virtual and Augmented reality for training and other services (STAR, 2004). A high degree of automation in 3D reconstruction should benefit all these application areas.

The quick acquisition of 3D data as well as the automatic data processing is two key-tasks for the majority of surveying fields. Airborne laser scanning systems generate 3D data with high speed, good accuracy and density. Thus, the use of this technique in urban region is more and more frequent.

In order to construct automatically 3D city models, two successive steps have to be considered. The first one is the automatic segmentation of the point cloud into three classes which are terrain, vegetation and buildings. Once the city cloud is segmented, the modeling of buildings can start. Two types of approach called ‘model-driven’ and ‘data-driven’ approaches in the literature are proposed for constructing building models. The model-driven approaches search the most appropriate model among primitive building models contained in a model library

(Maas and Vosselman, 1999). They consider that a primitive building can be described by a set of parameters. That implies to calculate the values of the parameters before constructing the 3D model. On the other hand, data-driven approaches try to simulate each part of the building point cloud for obtaining the nearest or the more faithful polyhedral model (Rottensteiner, 2003). In the context of data-driven approaches which provide more universal models, the automatic detection of planes is a crucial operation. Many methods are proposed in order to carry out this procedure such as region growing, 3D Hough transform and RANSAC.

Hough transform is a powerful technique for the determination of parameterizable patterns in binary images. It is essentially a voting process where each feature point votes for all the possible patterns passing through that point. The votes are accumulated in an accumulator array, and the pattern receiving the maximum vote is considered to be the pattern in the image. The advantages of the transform are its robustness to noise and discontinuities in the patterns. On the other hand, high computational and storage requirements are the drawbacks of the transform. Examples of parameterizable patterns are straight lines, circles, ellipses, etc (Hough, 1962).

## 2. RELATED WORKS

The 2D Hough transform technique is normally used in the field of digital image processing in order to detect geometric primitives (Hough, 1962). In this field, many applications together with its algorithm are presented (Davies, 1988; Gonzalez et al., 2004; Nguyen et al., 2005). This technique is used to detect

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\* Corresponding author.

the straight lines like building contour polygons and curves such as circles and ellipses. With the 3D point cloud, the 2D Hough transform has been extended to 3D for detecting 3D planes (Vosselman and Dijkman, 2001; Oda et al., 2004; Overby et al., 2004). Then, its principle has been extended to the extraction of other 3D geometric forms like cylinders (Rabbani and Van den Heuvel, 2005).

Rabbani and Van den Heuvel (2005) presented an efficient Hough transform for detection of cylinders in point clouds. Although Hough transform can be used for automatic detection of cylinders, the required 5D Hough space has a prohibitively high time and space complexity for most practical applications. They addressed this problem and presented a sequential Hough transform for automatic detection of cylinders in point clouds.

Atiquazzaman and Akhtar (1994) developed the algorithm to detect the length and the end points of a line. But the accuracy of detection is dependent on the accurate detection of the line parameters. As well, the algorithm is not effective in determining the end points of the line if the  $\rho$  and  $\theta$  parameters cannot be detected accurately. Hence, the method described Atiquazzaman and Akhtar is not suitable in those cases where the peak cannot be detected accurately. The algorithm described by Richards and Casasent (1991) is also based on the accurate determination of the peak and hence suffers from the same drawback experienced by Atiquazzaman and Akhtar. Atiquazzaman and Akhtar (1995) developed a robust algorithm to detect the lengths and the end points of straight lines. The proposed algorithm is based on an analysis of the distribution of votes around the peak in the accumulator array. The algorithm proposed doesn't use the values of  $\rho$  and  $\theta$  parameters of the line in order to detect the end points, and hence is independent of the accuracy with which the line parameters can be detected.

Tarsha-Kurdi et al., (2007) focused on the Hough transform and the RANSAC (Random Sample Consensus) algorithm. They made an analytic comparison of both algorithms, in terms of processing time and sensitivity to cloud characteristics. Despite the limitation encountered in both methods, RANSAC algorithm is more efficient than the Hough transform. The main advantage of RANSAC algorithm is rapidity and the percentage of successful detected roof planes. On the other hand, Hough transform is very sensitive to the segmentation parameters values. Therefore, RANSAC algorithm has been chosen and extended to allow harmonizing the mathematical aspect of the algorithm with the geometry of a roof.

Ballard (1981) developed the generalized Hough transform to detect arbitrary shapes. Using the GHT we are able to detect the shape no matter whether it is shifted, rotated or optionally even scaled in the image. We need these degrees of freedom, since the orientation is only known approximately. Additionally the GHT allows for a certain tolerance in shape deviation, which is necessary, since the CAD model of the building is only a coarse generalization of its actual shape as it appears in the image.

### 3. HOUGH TRANSFORM

The principle of the 2D Hough-transform is the representation of a points set, defined initially in the Euclidian space, in another space. This transform allows detecting the points composing specific geometric primitives.

For example, in (OXY) space, the equation of a line has the form (1).

$$Y = a \cdot X + b \tag{1}$$

where (a, b) are the line parameters.

This line can be represented by a point with coordinates (a, b) in the parameter space (O' a b). In an opposite way, one point (X<sub>i</sub>, Y<sub>i</sub>) belonging to the space (OXY) is represented by a line in the parameter space (O' a b) as expressed in Equation 2.

$$b = -X_i \cdot a + Y_i \tag{2}$$

where (X<sub>i</sub>, Y<sub>i</sub>) are the parameters of this line.

Supposing that M<sub>1</sub>, M<sub>2</sub>, ..., M<sub>n</sub> are a set of points in the space (OXY) and that they belong to the line P following Equation 1. Each one of these points represents a line in the parameter space. The intersection of these lines in the parameter space is the point (a<sub>1</sub>, b<sub>2</sub>) which represents the parameters of the line P in a 2D-space.

If the line equation has the form X = constant, then it cannot be presented in the parameter space (O' a b), because the Y-axis coefficient is equal to zero. In order to solve this problem, it is suggested to use the normal form of the line (Equation 3).

$$\cos \theta \cdot X + \sin \theta \cdot Y = \rho \tag{3}$$

where  $\theta$  and  $\rho$  are the parameters of the normal passing through the origin (see Fig.1).

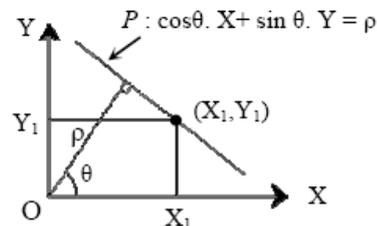


Figure 1. Presentation of one line and its normal in a 2D-space

So,  $\theta$  and  $\rho$  are constant for one line. The parameter space in this case is (O'  $\theta$   $\rho$ ). Hence, one point (X<sub>1</sub>, Y<sub>1</sub>) in the 2D-space represents a sinusoid in the parameter space (see Fig.2).

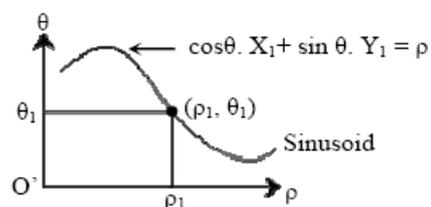


Figure 2. Presentation of a point in the parameter space using the normal form

### 4. EXPERIMENTS

At this study, we used laser data of Stuttgart city center which are utilized before to evaluation of filtering techniques by ISPRS

Commission III. These areas (Table 1) were chosen because of their diverse feature content (open fields, vegetation, buildings, roads, railroads, rivers, bridges, power lines, water surfaces, etc.). The point densities for the City are roughly 0.67 points per square meter (point spacing: 1.0 - 1.5m). 3D images of the Site2, Site3, and Site4 are presented in Fig.3.

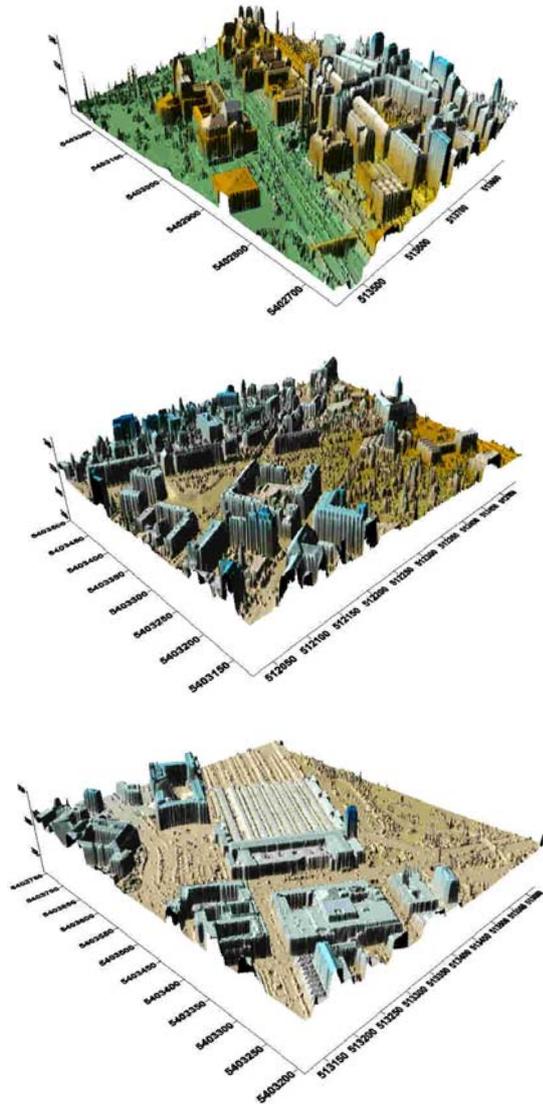


Figure 3. 3D images of Site2 (above left), Site3 (above right), and Site4 (bottom)

Site	Features of interest
Site2	Large buildings, irregularly shaped buildings, Road with bridge and small tunnel, and Data gaps.
Site3	Densely packed buildings with vegetation between them, Building with eccentric roof (bottom left corner), Open space with mixture of low and high features, and Data gaps.
Site4	Railway station with trains (low density of terrain points) and Data gaps.

Table 1. Features of interest of the Site

In the phase of preparation of laser data, second laser pulse data were selected due to representing the objects (building, bridge,

trees etc.) above ground. Firstly, laser data were transformed to grid format (1×1m) by using Kriging interpolation method via surfer 8.0 software (Fig.4). Then, the images obtained from here were imported to MATLAB software. Filtering, enhancement and edge detection with Hough transform operations were made in Image Processing Toolbox of MATLAB.

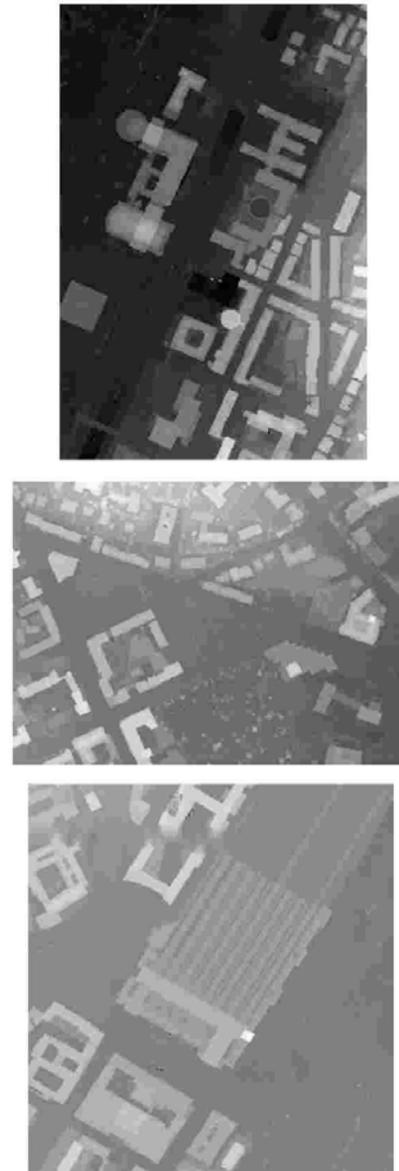


Figure 4. Grayscale images of Site2, Site3, and Site4 obtained from Surfer 8.0

## 5. RESULTS

On this study, we studied to detect 2D building details by Hough transform. Firstly, we made morphological operations (dilating and eroding) on the grayscale image (Fig.5). Thanks to this operator, study area was extracted obviously. After that, canny edge detector was applied the images to find the edges. Thresholds value was selected 0.1 and 0.2. Also, the smoothing constant was determined as 2. The smoothing has to remove the high spatial frequency texture in the background. Finally, the Hough transform was performed the images separately. This transform allows detecting the points composing specific

geometric primitives (Fig.6).

The Hough function implements the Standard Hough Transform (SHT). The SHT uses the parametric representation of a line:

$$\rho = x.\cos\theta + y.\sin\theta \quad (4)$$

The variable  $\rho$  is the distance from the origin to the line along a vector perpendicular to the line.  $\theta$  is the angle between the x-axis and this vector. The Hough function generates a parameter space matrix whose rows and columns correspond to  $\rho$  and  $\theta$  values respectively. Peak values in this space represent potential lines in the input image.

To find the peaks in the transform, we used the Hough function to locate the peak positions. The maximum number of peaks to find is 21, and peaks must not be closer than 27 bins in  $\rho$  and 11 bins in  $\theta$ .

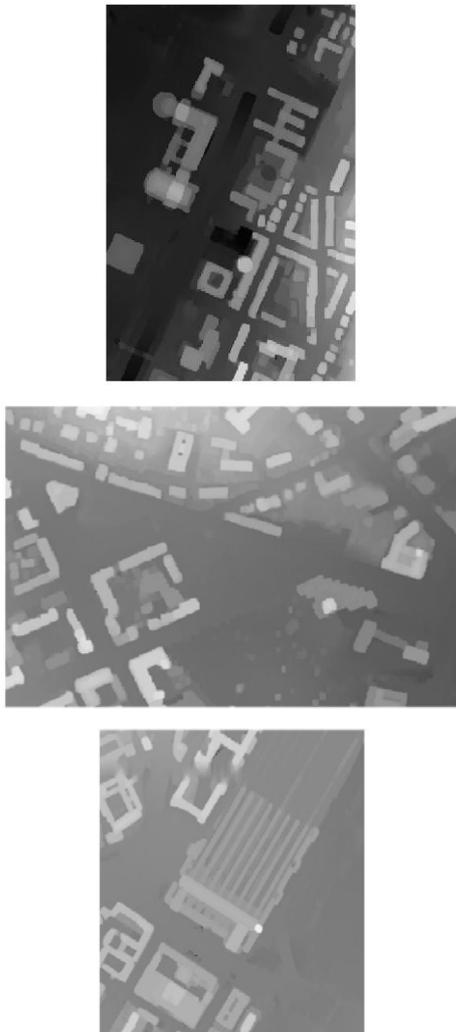


Figure 5. Morphological operations was performed the images

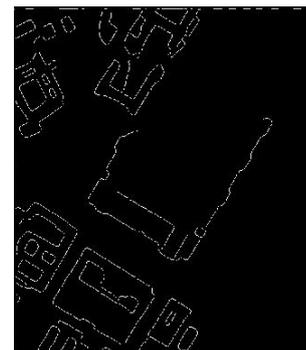
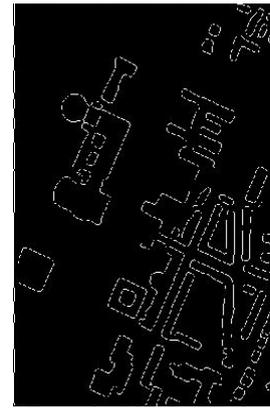


Figure 6. The images which were detected the edges by Hough transform

## 6. CONCLUSIONS

In this study, we tried to detect the building details from laser scanner data by using grayscale images. Therefore, we evaluated the images via MATLAB software. In this phase, several image processing techniques were applied the images. After that, Hough transform was performed to detect lines of building. The advantage of the Hough transform, the lines of the objects are obtained very quickly. The negativity of this transform cannot to be extracted clearly. Especially, the details of Site4 cannot to be extracted at desired level due to included low density terrain points.

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