

# 3D MODELLING OF THE HERITAGE BUILDINGS BY USING MUSCLE MODEL

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**Abstract:** *MUSCLE (Multidirectional Scanning for Line Extraction) Model is a conversion method which was developed to vectorize the straight lines through the raster images including township plans, maps for GIS, architectural drawings, and machine plans. By using this model, it is also possible to generate 3D Building models based on the floor plan of the building. In the MUSCLE, to generate 3D building model, first image of the floor plan should be pictured on the form of the user interface. The 3D models of the buildings can be then generated automatically by analyzing and processing these images. In this study, the MUSCLE Model was implemented in Safranbolu which is a famous city within the UNESCO World Heritage List. A historical Safranbolu house were modelled in 3D by using this method. The results indicate that the MUSCLE model can be eligibly used to generate 3D models of heritage buildings.*

## 1. INTRODUCTION

MUSCLE (Multidirectional Scanning for Line Extraction) Model is a conversion method which was developed to vectorize the straight lines through the raster images including township plans, maps for GIS, architectural drawings, and machine plans. Unlike traditional vectorization process, this model generates straight lines based on a line thinning algorithm, without performing line following-chain coding and vector reduction stages. By using this model, it is also possible to generate 3D Building models based on the floor plan of the building.

Architectural plans of the buildings are generally either drawn on a paper as blueprints or stored in vector format. Blueprints can be stored in raster format after scanned by a scanner. Whether floor plan information is in raster or vector format, or even drawn on a form by a user, this method can be applied in any case. The key point is that images of the floor plan should be pictured on the form of the user interface. The 3D models of the buildings can be then generated automatically by analyzing and processing these images.

In this study, the MUSCLE Model was implemented in the Safranbolu which is a famous city within the UNESCO World Heritage List. A historical Safranbolu house were modelled in 3D by using this method. The results indicate that the MUSCLE model can be eligibly used to generate 3D models of heritage buildings and creates in a 3D geo-database.

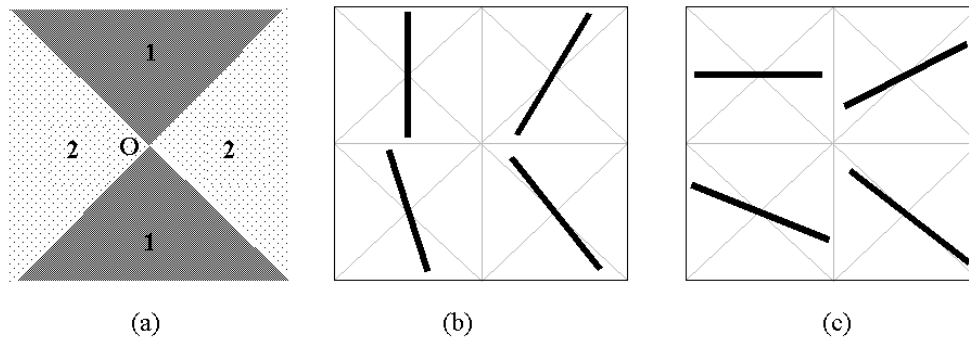
## 2. THE MUSCLE MODEL

### 2.1 Threshold Processing

In the threshold process, a predetermined grey level (threshold value) is to be determined and every pixel that is darker than this level is assigned black, while every lighter pixel is assigned white. Therefore, the greyscale image was converted into a binary image [1].

### 2.2 Horizontal and Vertical Scanning of the Binary Image

In this stage, the horizontal and vertical lines were extracted from the binary image. The nearly vertical lines were obtained by scanning the images horizontally, while the nearly horizontal lines were obtained by scanning the images vertically. The forms of nearly vertical and nearly horizontal lines are shown in Figure 1. In Figure 1a, the lines which pass through the region 1 and 2 are defined as the nearly vertical lines and the nearly horizontal lines, respectively. Figure 1b and Figure 1c indicates the sample drawings for nearly vertical and nearly horizontal lines, respectively.



**Figure 1:** Samples for nearly vertical and nearly horizontal lines.

At the first step, each row on the binary image was scanned horizontally to determine the thickness of the lines and the position of the pixels, which were located in the mid-point of the lines. During this process, the value (black or white) of each pixel was checked by moving from left to right. Once the first black pixel was met, its column number was stored into the algorithm. While continuing to scan pixels, the column number of the first white pixel was also stored into the algorithm. Thus, the position of the middle pixel in the mid-point of the line could be determined by using the following equation, based on the image coordinate system:

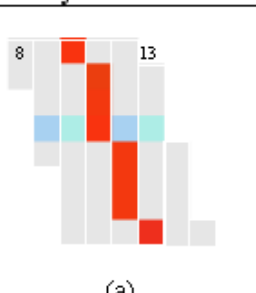
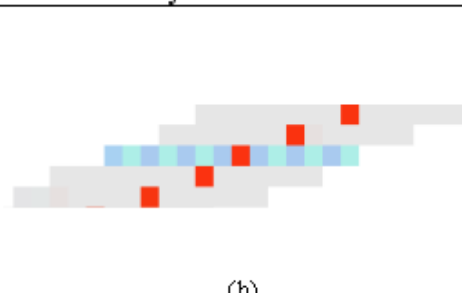
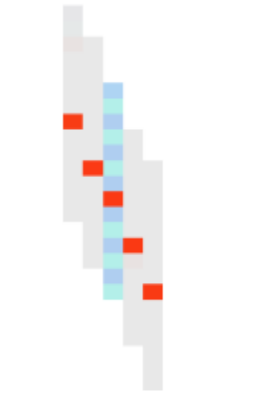

$$\text{The position of the middle pixel} = m + \text{Absolute Value} ((n - m) / 2) \quad (1)$$

$m$  : column number of the first black pixel

$n$  : column number of the first white pixel

For example, assuming that 8<sup>th</sup> pixel is the first black pixel and 13<sup>th</sup> pixel is the first white pixel in Figure 2a. Using Equation 1, position of the middle pixel can be calculated as 10<sup>th</sup> pixel, which is then colored with red. After performing the same process for each row on the image, distribution of the red pixels for nearly vertical and nearly horizontal lines are indicated in Figure 2a and Figure 2b, respectively. In these figures, the distribution of the red pixels indicates that the red pixels have continuity for nearly vertical lines; however they have discontinuity for nearly horizontal lines.

After the horizontal scanning processes were completed, only the red pixels were selected. Then, a neighborhood analysis was carried out based on the nearly vertical lines by taking the advantages of discontinuity on the nearly horizontal lines. In this method, a red pixel, which is adjacent to another red one, was searched along the lines. This process continued until no red pixels were found adjacent to each other, indicating that the end of the line has been reached. The beginning and ending points of all the nearly vertical lines were determined by using the same procedure.

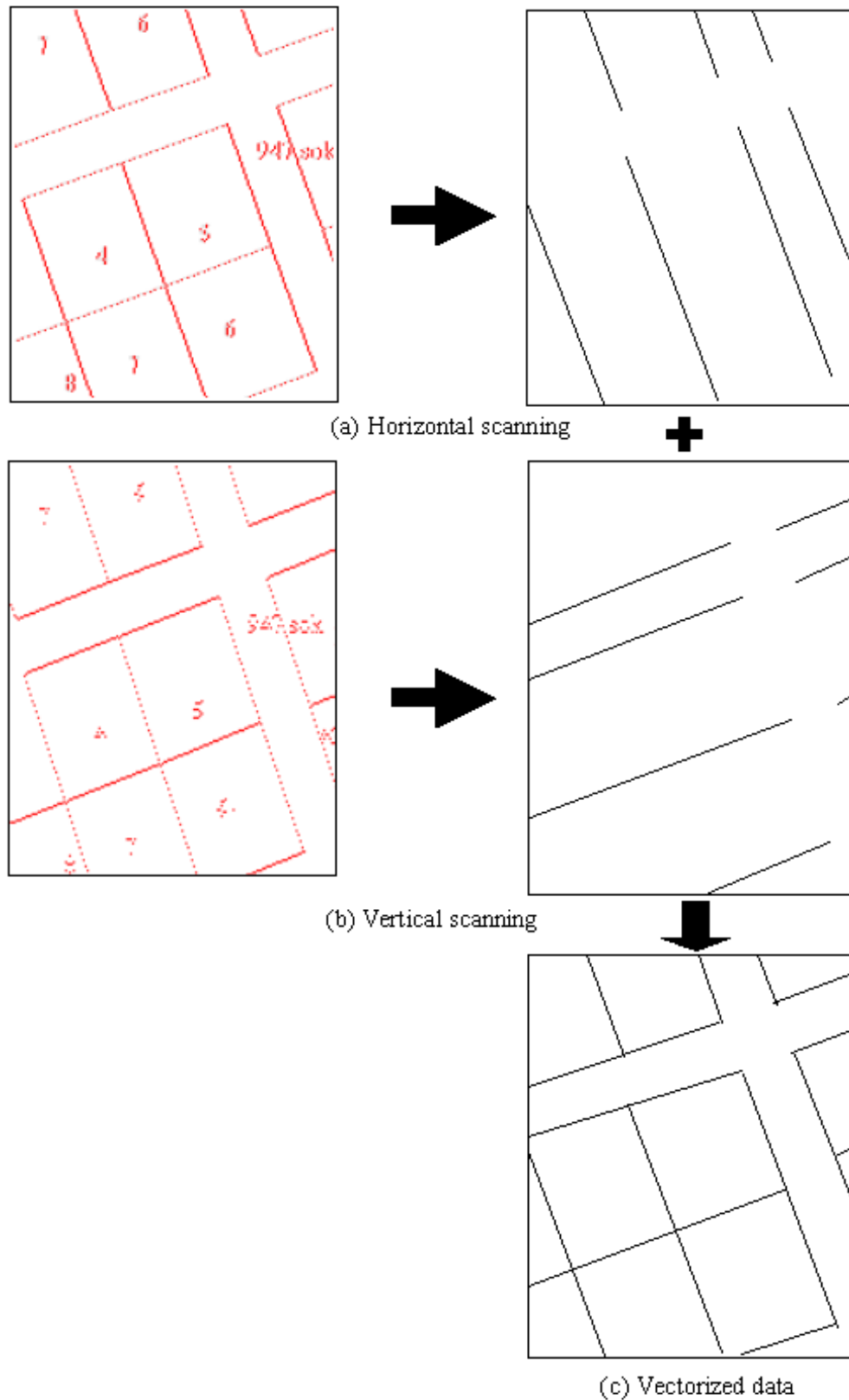
	Nearly Vertical Lines	Nearly Horizontal Lines
Horizontal Scanning	 <p>(a)</p>	 <p>(b)</p>
Vertical Scanning	 <p>(d)</p>	 <p>(c)</p>

**Figure 2:** Determining red pixels by using horizontal and vertical scanning process.

At the second step, the binary image was scanned vertically, and then, the same process described above was carried out for all columns. Unlike horizontal scanning, the red pixels have continuity for nearly horizontal lines (Figure 2c); however they have discontinuity for nearly vertical lines (Figure 2d). Therefore, the neighborhood analysis was carried out based on the nearly horizontal lines and the beginning and the ending points of all the plenary horizontal lines were determined. After completing the horizontal (Figure 3a) and vertical (Figure 3b) scanning of the binary image, the final vectorized data (Figure 3c) was generated by vectorizing the nearly vertical and the horizontal lines [2].

### 3. GENERATION OF 3D MODEL OF AN HISTORICAL SAFRANBOLU HOUSE

Safranbolu is the one of the most outstanding example of the traditional Turkish Architecture and also unique itself in terms of conservation of the human settlement in their authentic environmental motif up till now. The historical buildings built with a spectacular architectural knowledge reflect and brings the existing custom and multicultural from past to present. There only 1120 works of arts among the countless cultural arts have been taken to conservation. At the end of 1994, UNESCO has put the historical Safranbolu settlement into the world heritage list as its natural entity has been well conserved throughout all the years up to now [3]. There are two separately protected areas in Safranbolu and on that sense it looks like an open-air museum [4].



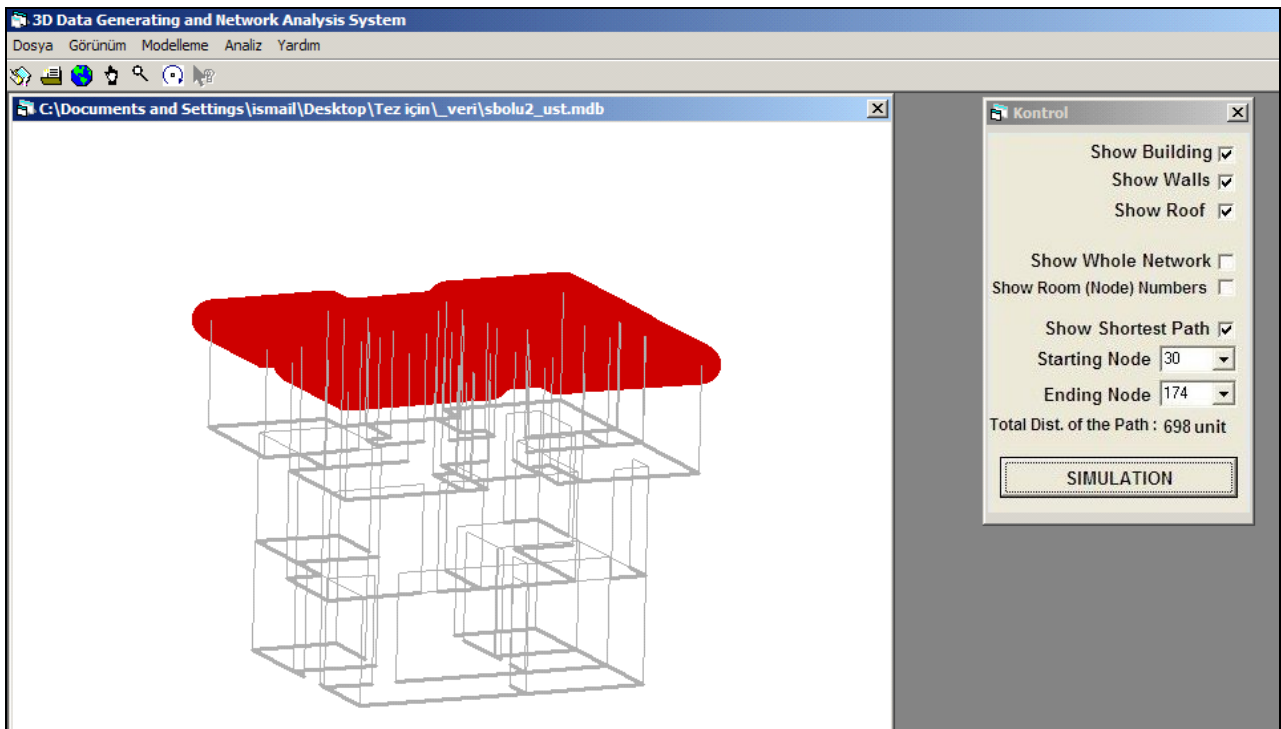
**Figure 3:** Horizontal and vertical scanning in vectorization process.

In this study, the MUSCLE Model was implemented in Safranbolu which is a famous city within the UNESCO World Heritage List. A historical Safranbolu house, which had been burned last year, was modeled in 3D by using this method. This house used to be known as Hatice Hanım Mansion and it was 474 years old.

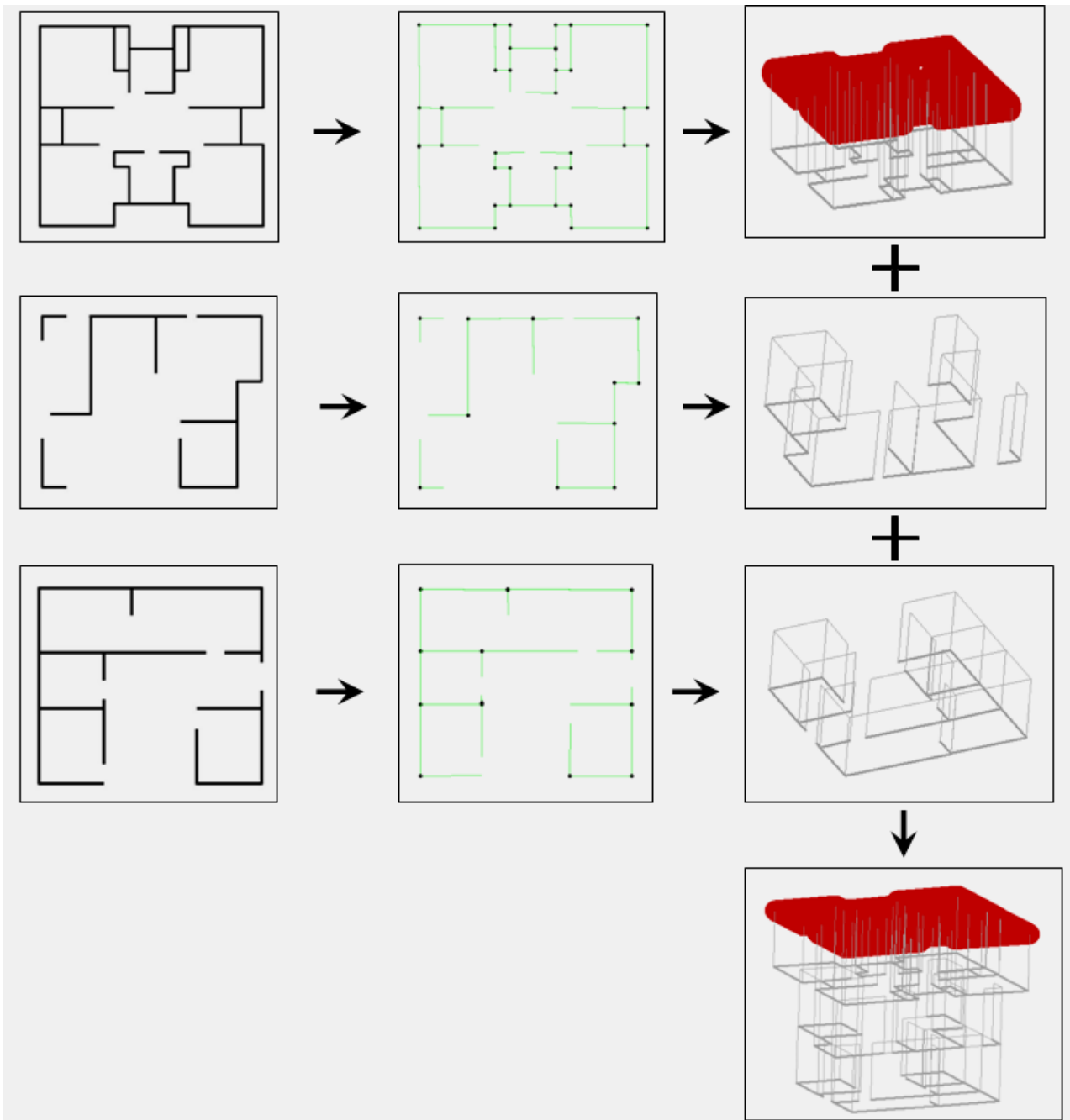


**Figure 4:** Hatice Hanım Mansion, before and after the fire.

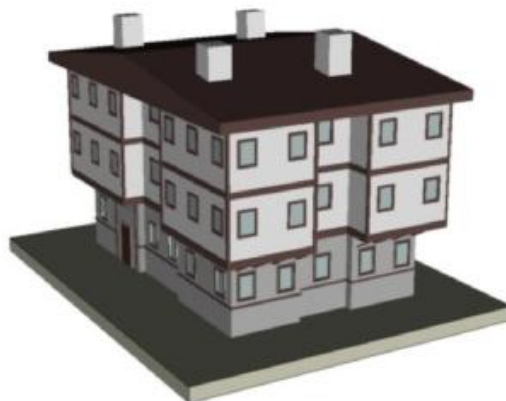
By using the MUSCLE Model (Multidirectional Scanning for Line Extraction) as described in the preceding sections, the 3D model of this building can be generated automatically from raster floor plans. The user interface of 3D Model Generation Software is shown Figure 5. In the process, as shown in Figure 6, for each floor first, lines are determined. Then lines and points, both generated the floor plan, are obtained by determination of intersection points using optimization process. Based on user defined data such as heights, 3D model of each floor is generated. Then, 3D models of ground, middle and top floors are combined together and thus created the 3D house model. Lastly, features of the building are automatically stored in the created 3D Geo-Database. The outcome of the software can also be exported to the CityGML format. After some façade construction process on CityGML format, the 3D model of the house can be obtain as Figure 7.



**Figure 5:** 3D Model Generation Software



**Figure 6:** Automatically Generation of 3D Model of Hatice Hanim Mansion by using ground, middle and top floors architectural plan.



**Figure 7:** 3D model of an historical Safranbolu house, after façade construction on CityGML format.

#### **4. CONCLUSIONS**

Since 1947, twenty-two heritage buildings of Safranbolu have been burned for a variety of reasons. The last one, Hatice Hanim Mansion, used to be valued at within the first fifty in the aspect of characteristic traditional Turkish architecture [5].

In this study, MUSCLE Model (Multidirectional Scanning for Line Extraction) was used to automatically extract 3D Model of this historical Safranbolu house from the architectural plan of it. We believe that, this kind of 3D model generation works contribute to the reconstruction of the historical cities. Especially, to renovate the damaged buildings, these 3D models can be used for visualization. The results indicate that the model can be eligibly used to generate 3D models of heritage buildings and create to the 3D geo-database.

#### **5. REFERENCES**

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