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DOCUMENTATION OF HISTORICAL STRUCTURES IN THE COURTYARD OF MEVLANA MUSEUM BY TERRESTRIAL LIDAR AND PHOTOGRAMMETRY

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ABSTRACT

Mevlana Dervish Lodge, which is the place from where the ideas of Mevlana that embraces the world with tolerance, love and humanistic values had been spread, is today a museum sheltering the tomb of Mevlana. It is visited by people from all around the world. The Mevlana Museum is the form of a social complex that has many surrounding historical structures. There is no documentation reflecting the current status of structures around the building due to either lack of performance of a detailed documentation or modifications made in time. In this study; kitchen, dervish rooms and historical ablution fountain within the courtyard of the Mevlana Museum have been measured and documented in detail by terrestrial laser scanning and photogrammetry methods. The laser scanning measurements have been registered consecutively by the iterative closest point (ICP) method, and point cloud model has been composed. Global registration has been applied to point cloud model which has been created in order to decrease the error resulting from the registration consecutively. Then three-dimensional (3D) digital models have been composed by covering the point cloud with texture by the photogrammetric images. Moreover, detail measurements of the object have been provided by composing the inter section of the model with the determined reference plane and digital elevation model has been generated.

KEYWORDS: terrestrial laser scanning, LIDAR, photogrammetry, data integration, 3D modelling, point cloud, documentation

1. INTRODUCTION

The prevention of historical structures is very important in respect of documenting the roles of communities at the scene of civilization. Thus, many worldwide active organizations have been established for the protection of cultural heritage and for the continuity of cultural diversity. Among these, CIPA (The International Committee for Documentation of Cultural Heritage) is the documentation committee of ICOMOS (International Council on Monuments and Sites) for the international historical artifacts and it has been established in cooperation with ISPRS (International Society for Photogrammetry and Remote Sensing). Documentation of historical structures means measuring and recording of their location, form, size and textures as to enable their reconstruction when they fall into ruin or tumble down. There are numerous documentations which have been made by different techniques in the archives of CIPA and ISPRS (Remondino et al., 2012; Kulur and Sahin, 2008; Akca et al., 2006; Bosch et al., 2005; Toz and Duran, 2004; Lingua et al., 2003).

The methods arising through the developing technology makes measurement of historical structures possible along with all their details. These methods can be used alone or together in accordance with the purpose (Grussenmeyer et al., 2011; Remondino, 2011; Guidi et al., 2009; Yastikli, 2007, El-Hakim et al., 2004). Terrestrial laser scanner (TLS) is widely being used in the generation of three-dimensional (3D) models of historical structures. Laser scanner measures depict object shape with high density spatial point data.

All kinds of geometrical information about the object can be obtained from the 3D model generated by spatial data. However the 3D model generated by the measures of laser scanner does not cover texture information of the measurement area (Pfeifer and Briese, 2007; Boehler et al., 2003). Thus, 3D digital models (photo-realistic model) are being composed by covering the point cloud with texture by the photogrammetric images.

In this study; it has been intended to measure in detail and to document the kitchen, dervish rooms and historical ablution fountain within the courtyard of the Mevlana Museum. Due to modifications and additions made in time, the previous documentations on these sections do not reflect the current status. In this study, a detailed documentation of the interested structures has been made by laser scanning and photogrammetry. After measuring the object details by laser scanner, the point cloud model has been covered with texture by the photogrammetric images. Moreover, the details have been designed and digital elevation model has been created.

2. STUDY AREA

Mevlana Museum is at the city center of Konya. It is in the form of a social complex covering the tomb of Mevlana Celaleddin Rumi and the surrounding prayer room, semahane, kitchen, dervish rooms, ablution fountain, pool of night of union and gentleman chamber (Fig. 1).

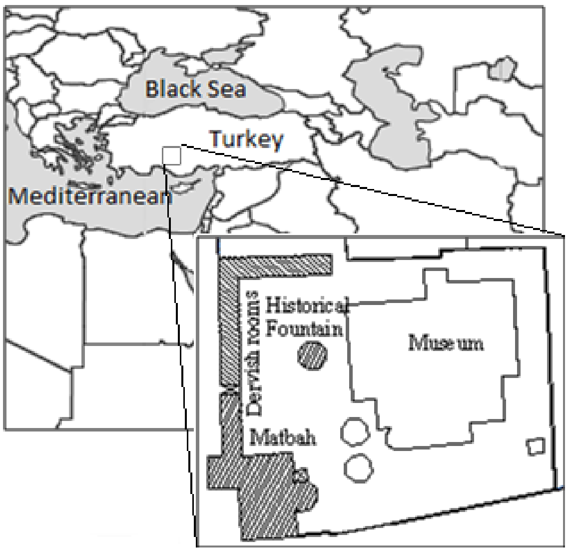

Figure 1 Location of the study area.

The tomb building among the structures composing the social complex had been constructed during the period of Seljuks. And the kitchen, dervish rooms and ablution fountain belongs to the period of Karamanids and Ottoman Empire. Mevlevi Dervish Lodge and Tomb have been started to be used as Museum after 1926, and the name of the Museum has been changed as Mevlana Museum in 1954 (URL-1).

Gate of dervishes is used to enter the courtyard of the Museum. Dervish rooms are located along the north and west side of the courtyard, and kitchen and Hurrem Pasha Tomb are located at its southern. And on the east of the courtyard, a building composed of semahane, pareyer room section and Mevlana Tomb is located near the tombs of Sinan Pasha, Lady Fatma and Hasan Pasha (URL-1).

The sheltered ablution fountain (Fig. 2), which had been constructed in 1512 by the order of Selim I, embellishes the courtyard. The ablution fountain had been repaired in 1595 and 1868 for the first time. The ablution fountain, whose cover coat had collapsed in 1930 and whose columns had been destroyed, has been reconstructed in 1989 in accordance with its original.

Figure 2 Kitchen, dervish rooms and historical ablution fountain within the courtyard of the Mevlana Museum.

There exist 17 rooms that surround the west and north directions of the front courtyard of the Mevlana Dervish Lodge each having a small dome and funnel (Fig. 2). These rooms had been constructed in 1594 by the order to Murat III for the residence of dervishes. These are being exhibited by their original furniture as postnisin and mesnevihan chambers. And in the showcases built on the windows and door spaces of the rooms that open to the corridor, historical goods transferred from the dervish lodge to the museum such as tongs of stallholder, mutteka, salpinx of Mevlevi ethnography and extremely valuable fabrics of the museum's collection are being exhibited (URL-1).

The kitchen is located on the southwest corner of the museum. It had been constructed in 1584 by the order of Sultan Murat III. The food was being served from here until 1926 when the dervish lodge turned to a museum. After the repairs in 1990, the exhibition and arrangement of this section had been reorganized by the mannequins. Cooking -being the main function of the kitchen- and having meal on the table called somat has been tried to be displayed by the mannequins. The sema grandfather having the Mevlevi dervish candidate–called spirit-exercise sema near the sema exercise nail, while the Nevniyaz -the candidate for nomination as Mevlevi- is sitting on the goldfinch fur has tried to be figured as another function of the kitchen (URL-1). Kitchen was the place where the 1001 days training of individuals -who wanted to be Mevlevic dervish and who were called as spirit- was held as well as being a place where the food of Mevlevis were being cooked (Mevlana Museum, 2012). Hurrem Pasha Tomb is located as adjacent to the east façade of the kitchen.

3. FIELD STUDIES

3.1 Spatial Data Acquisition

The structures has been measured by Ilris 3D laser scanner instrument. The instrument measures by the method of time-of-flight, and the measurement distance is in between 3-1200m. Measurement accuracy of the instrument is 7mm at a distance of 100m, and its measurement rate is 2500 points/seconds (Optech, 2012). Laser scanning measurements have been performed about 20 meters away at 62 stations, and 2550000 points have been measured (Fig. 3).

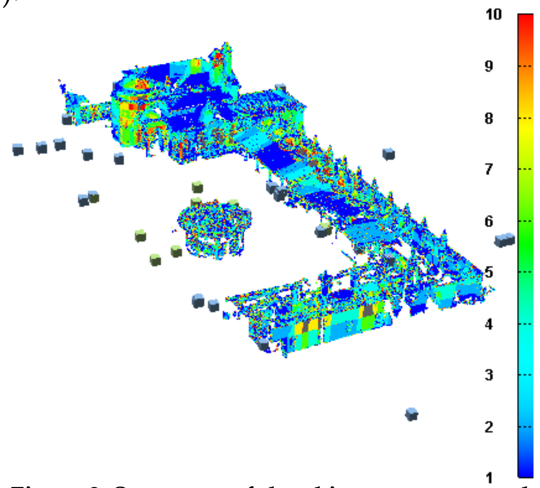

Figure 3. Some part of the objects were scanned many times with overlap measurements. The color legend on the right shows the repeated measurements (Red color shows 10 times measurement).

As the point separation (distance between measured points) changes as per the distance in between the TLS instrument and the measured detail, it has been adjusted as approximately 1.5cm.

3.2 Texture Data Acquisition

Texture information has been obtained from photogrammetric images recorded by the Nikon P50 camera. The calibration of the camera has been made by using a special calibration grid prior to taking the images (Table 1).

The computed parameters on the Table 1 are standard on the camera calibration (Fraser and Al-Ajlouni, 2006). Where; *c* is principal distance (focal length), *PPx* and *PPy* are principal point coordinates, *K1* and *K2* are radial distortion parameters and *P1* and *P2* are decentering distortion parameters.

Table 1. Nikon P50 numeric camera calibration results.

Pixel array	Pixel size (mm)	*c* (mm)	*PPx* (mm)	*PPy* (mm)	*K1*	*K2*	*P1*	*P2*
3264x2448	0.0016	4.5212	2.6891	2.0751	0.006056	-0.0000709	-0.000126	-0.000101

4. RESULTS

4.1 Point Cloud Model

In order to generate the 3D model, first it is required to combine the point cloud measurements obtained from different stations on a single coordinate system. The combining of point clouds is the registration (3 translations and 3 rotations) of all point clouds into coordinate system selected as a reference. Different methods are being used in combining the point clouds of laser scanner (Chen and Medioni, 1992; Besl and McKay, 1992; Gruen and Akca, 2005; Al-Manasir and Fraser, 2006; Bernea and Filin, 2007; Aquilera et al., 2009). The ICP (iterative closest point) is a high accuracy method being widely used in practice. In this method, the registration parameters between the overlapping point clouds are calculated by the closest pairs of points, and it is carried out for the target (moving) point cloud (Chen and Medioni, 1992; Besl and McKay, 1992). The operation proceeds iteratively until the difference in between successive iterations is minimum or the iteration number reaches a specific value. For the implementation of the ICP, the initial approximate registration of the point cloud have to be made. Depending on the precision of the initial registration, the registration is generally obtained in about fifteen iterations. In this study, the approximate registration parameters have been calculated by at least three conjugate points selected from the overlapping scan area (InnovMetric, 2007).

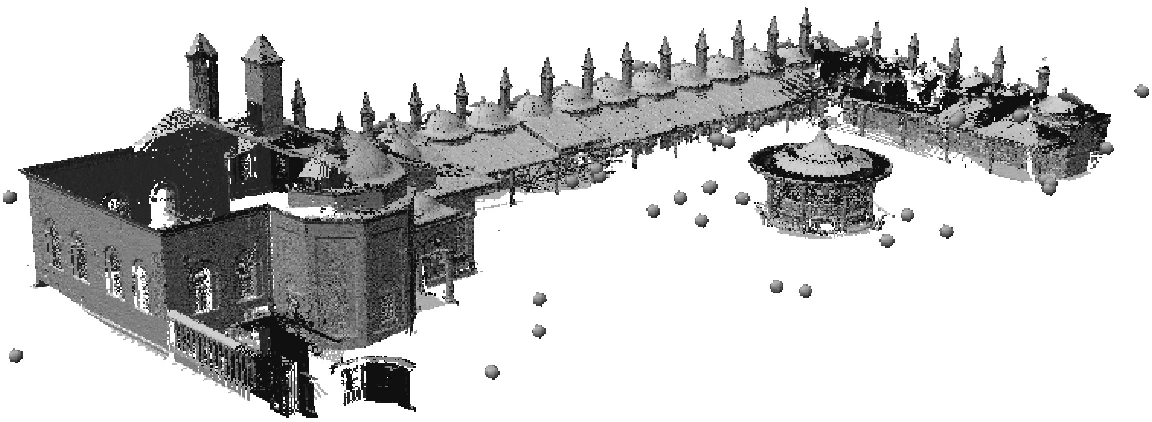

Figure 4. Generated point cloud model of the study objects. The points show the laser scanning stations.

The 3D point cloud model has been created in this manner by registering all the measures consecutively (Fig. 4). Despite the registration accuracy of the iterative method is high, in case of registration of numerous point clouds successively, the registration errors accumulate and becomes overmuch in the last. Thus, in the model generated, global registration has been applied with ICP method in order to minimize the effect of accumulated registration errors.

Table 2. Global registration results.

Point Cloud Model	Point Cloud #	Iteration #	Std. Deviation (cm)		
			Min.	Med.	Max.
Kitchen& Dervish rooms	46	35	0.10	0.87	1.26
Ablution Fountain	14	17	0.78	1.04	2.22

For the global registration, one of the point clouds has been selected as a reference and the registration of all the others relation to its coordinate system has been realized synchronically (Table 2).

4.2 Data Integration

3D point cloud shows the object details with the spatial data (xyz) without texture information. In order to add texture data to the model, point cloud must be covered with texture by the photogrammetric images. Covering with texture is realized in two steps. A triangulated surface (mesh) of the point cloud is created in the first step. In order to create similar size triangles on the surface of the model, the excessive points on the overlapping area have been removed prior to built of mesh image. In this study mesh surface has been generated with PolyWorks software (Fig. 5, Fig. 6).

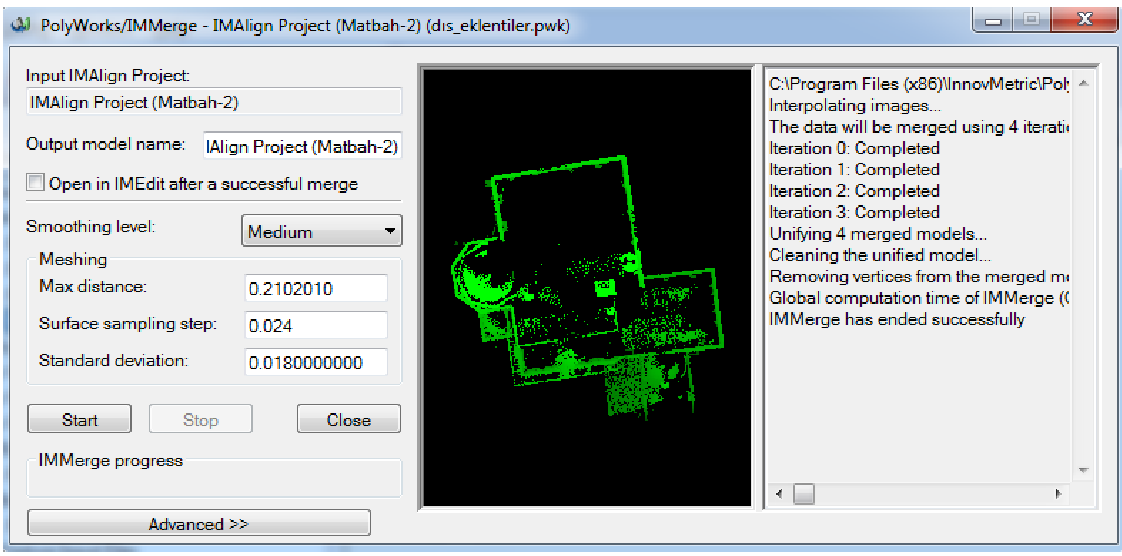

Figure 5. Setting and processing of the mesh creation from point cloud by PolyWorks.

Figure 6 Triangulated point cloud model.

(a) (b) (c)

Figure 7 a) 2D orthophoto image of the kitchen door. b) Texture mapped 3D model of the gate of dervishes and c) the historical ablution fountain.

In the second step, location and rotations of the image to be covered by texture as per the coordinate system of the point cloud are estimated. These parameters are calculated by space resection method by at least three and preferably more conjugate points selected from the image and point cloud. The texture of photograph corresponding to the triangulated surfaces of the point cloud is covered on the model. Thus, 3D model and 2D orthophoto images including texture and depth information have been created (Fig. 7).

4.3 Object Dimensions

For the determination of ground plan of structures, a horizontal plane has been defined and the ground plan has been generated by taking the inter section of this plane and the point cloud model. During generation of the cross section, since the point separation (point-to-point distance) is about 1 cm, the distance from points to the plane was taken smaller as 0.5mm (Fig. 8). Dimensions of the facade of the structures were measured over the generated plan (Fig. 9).

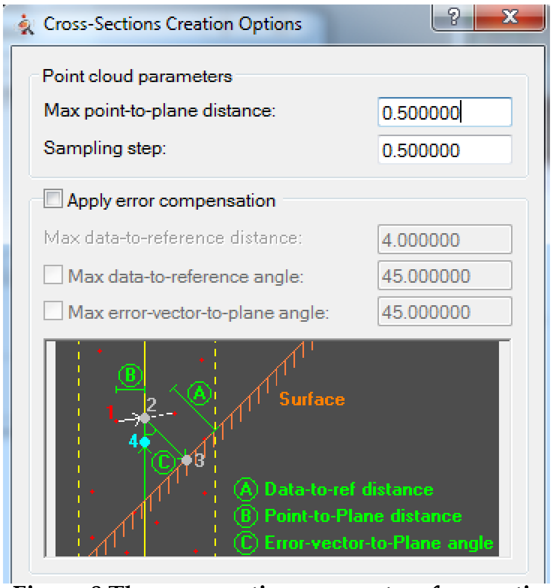

Figure 8 The cross-section parameters for creating ground plan (PolyWorks, 2007).

Moreover, digital elevation model has been composed in order to show the elevations in vertical direction. By the digital elevation model, the heights of the structure details from the ground can be distinguished and can be relatively compared (Fig. 10).

5. DISCUSSION AND RESULTS

In this study, the 3D digital model of kitchen, dervish rooms and historical ablution fountain among the additions of Mevlana Museum has been created by terrestrial laser scanner and photogrammetric measures. After combining the point clouds by the ICP, global registration has been applied to the model in order to minimize the cumulative error resulting from the registration consecutively. In the application of the ICP method, characteristic details such as corner, edge at the overlap scanning area increases the accuracy in the selection of closest conjugate point. Thus, the accuracy in the registration of the point clouds of ablution fountain having round and symmetrical details in general is low due to hardness of selection of conjugate points.

Consequently, the created 3D model has high accuracy. 3D virtual models and orthophoto images generated by covering the point cloud model with image contain both spatial and texture data. Moreover, the object sizes have been provided on the horizontal plane over generated cross-section, and the elevations of the details have been displayed relatively by the digital elevation model.

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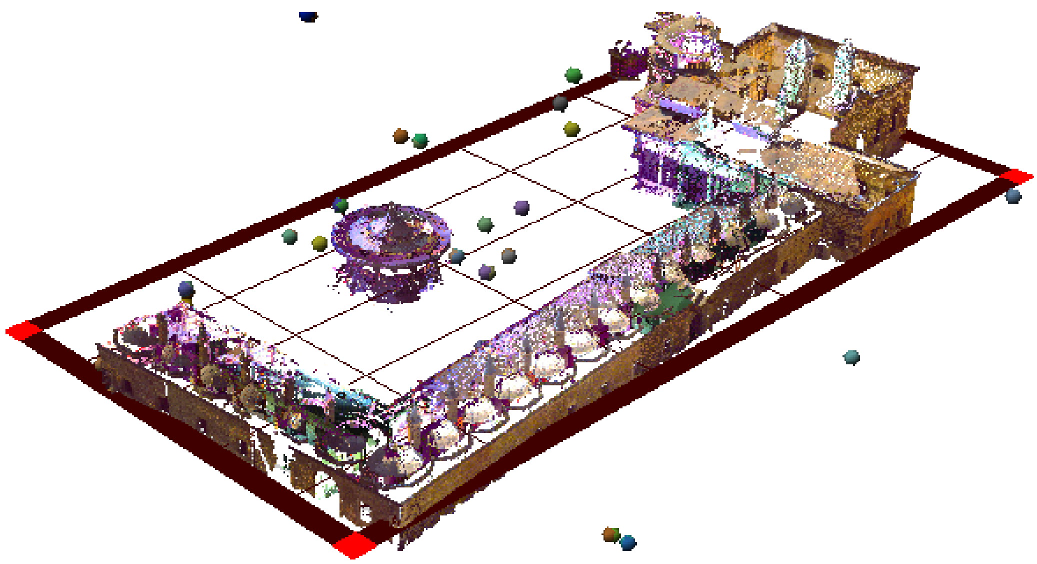

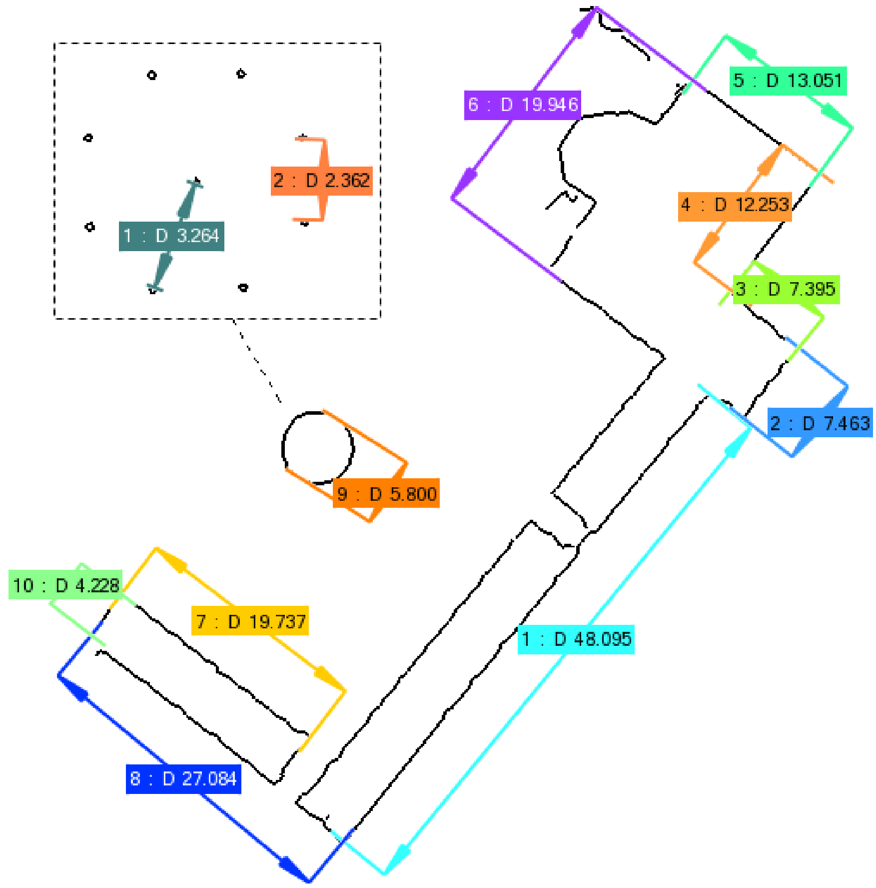

Figure 9 Ground plan that was created from cross-section of reference plane and point cloud and dimensions of the structures (units are meters).

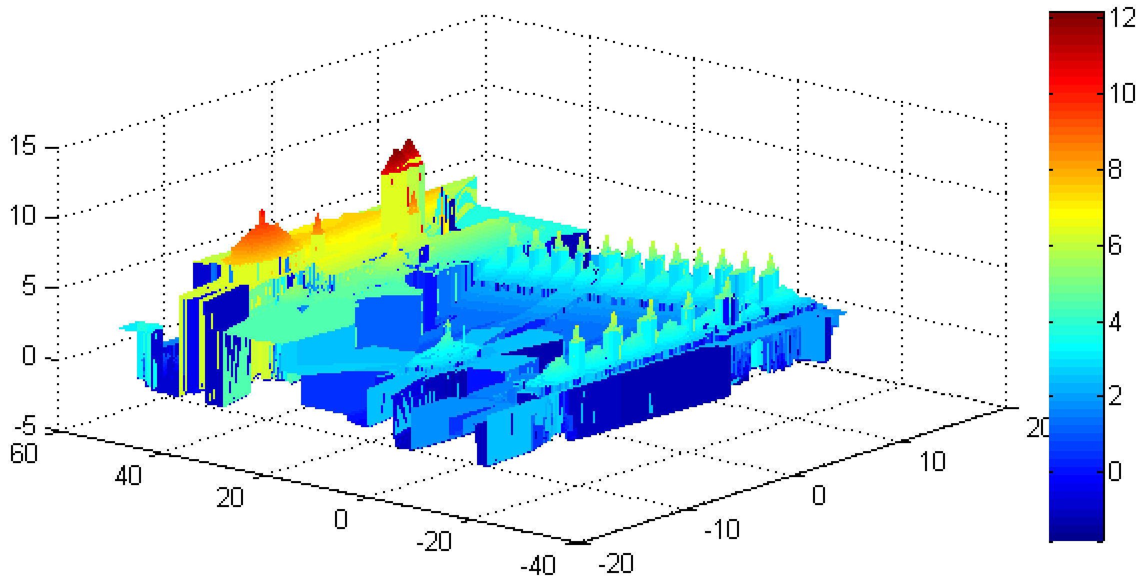

Figure 10 Digital elevation model generated from the point cloud data (units are meters).

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