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Full Length Research Paper

A study on measurement of building wall thickness from 3D object model

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Technological developments provide new methods for the measurement of 3D point data and information extraction from them. Terrestrial laser scanning is the latest method to 3D surveying and modeling. All geometric information belonging to the object or scene can be extracted from terrestrial laser scanner (TLS) data. The aim of this work is measurement of wall thickness of a building, which was built to protect the Alaaddin Palace, creating of cross-section by laser scanning data. We surveyed the building by TLS and performed 3D model. Then cross-sections were created from point clouds to measurement wall thickness of concrete building.

Key words: Terrestrial laser scanner, concrete building, cross-section, 3D modeling, wall thickness, Alaaddin Palace

INTRODUCTION

The TLS are frequently used in cultural heritage documentation (Boehler et al., 2003; El-Hakim et al., 2004, Yastikli, 2007), deformation and change monitoring (Gonslia et al., 2006), 3D modeling and visualization (Veinhaus and Devarajan, 1997) and to acquire 3D data for the other purposes. Also large and complex monuments and scenes can be measured in a short time. Point clouds are used for 3D modeling, visualization, simulation, computation like cross section, volume and area, and others.

The Alaaddin Palace was located at the center of Konya city in Turkey (Figure 1). It is a cultural heritage which belongs to Seljuk period and a big part has collapsed today. The heritage has been protected by concrete building. But it has become old due to the corrosions, which has been the effects of seasonal conditions since 1966. Wall thickness of the concrete building has decreased in the same part because of increasing corrosions.

Our aim in this study, is to determine corrosions by measuring the thickness from 3D point cloud model. The object was scanned by TLS and created cross-section with regular spaces. Its wall thickness was measured on cross-sections. Apart from this introduction, the rest of the article has been organized as a definition of terrestrial laser scanning, 3D modeling of the object, creation of cross-section from point cloud and conclusion in the last.

THE METHOD: TERRESTRIAL LASER SCANNING

Terrestrial laser scanning technology was introduced in the 1990s first. The laser scanners used time-of-flight (ToF) or phase-shift method and measure distance, horizontal and vertical angle from instrument, to each scanning point with millimeter accuracy. TLS can measure large number of points from 1,500 to 500,000 in per seconds. It collects 3D data (with 1:1 scale) and intensity from the object surfaces as rows consist of point series desired interval (Pfeifer and Briese, 2007; Scaioni, 2005). TLS can also record color data via the image of integrated camera.

Many researches can be found in literature about the accuracy of TLSs. Point position accuracy is a few millimeter less distance than 100 m, 1 cm less distance than 300 m and within 10 cm at 1000 m (Boehler et al., 2003; Johansson, 2002). To obtain occlusion free 3D model by TLS, the object should be scanned from many different stations. TLS coordinates are in the local system

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Figure 1. Heritage of the Alaaddin Palace.

center, that is the laser scanner instrument. Because of that, every scan should be registered into the reference coordinate system. The registration defines translation and orientation from one coordinate system into the other coordinate system. One of the scanning is selected as reference and the others are registered in relation to its coordinate system. So, the scanning has been made overlap with the adjacent scan. The overlap scanning areas are necessary for registration except some methods. The registration of second point cloud according to coordinate system of the first point cloud is made by Equation 1.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{TLS1} = R.\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{TLS2} + \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} \quad (1)$$

Here, TLS1 and TLS2 are coordinates of the first and second point clouds respectively, R is 3 x 3 rotation matrix computed by 3 rotation angles between coordinate axis. [Xo Yo Zo]T is coordinate origin of the second point cloud in coordinate system of the first point cloud.
There are different techniques for registration and combination of TLS point clouds. The most popular method is iterative closest point (ICP) algorithm (Besl and McKay, 1992; Chen and Medioni, 1992; Zhang, 1994). In ICP, rigit transformation parameters are estimated by the nearest point pairs in overlap area and then registration is applied to one of the partial overlapping point sets. The procedure is applied in iterative form until Euclidean distances between point of pairs become minimum (Besl and McKay, 1992; Chen and Medioni, 1992; Zhang, 1994). The other methods for registration are least square 3D matching (Gruen and Akca, 2005), image based registration (Al-Manasir and Fraser, 2006) and target based registration method (Scaioni, 2002).

3D modeling of the object

The concrete building was scanned by Optech Ilris 3D laser scanner. The TLS has got integrated camera on board. Its technical information is stated below:

Range distance: from 3 to 1500 m
Data sampling rate: 2500 points per second
Beam divergence: 0.00974o
Minimum spot step (X and Y axis): 0.00115o
Raw range accuracy: 7 mm @100 m
Raw positional accuracy: 8 mm @100 m
Inside and outside of the concrete building was scanned with about 3.5 mm point spaces and collected 8,440,464 points. The object was scanned from 24 stations to obtain an occlusion free 3D model. Each scan was done about 20 m distance from the object as overlap with adjacent scan.

To obtain 3D model, all scans were registered in relation to the coordinate system of the first scan which was related as reference. The registration was done by Polyworks commercial software using ICP method. Registration accuracy of all the models is about 1 mm as seen in Figure 2.

Cross-section

Cross-sections were created by IMInspect model of Polyworks commercial software, to determine wall thickness of building (Innovmetric, 2007). We defined reference plane perpendicular to the object surfaces and then cross-sections were created by crossing of the plane with the 3D point cloud model. They were obtained from one side to the other side in 1 m interval by this plane (Figure 4). To create cross-section in Polyworks software, Max point-to-plane distance and sampling step should be set in cross-section creation options dialog box (Figure 3) (Innovmetric, 2007). The details of cross-section creation options dialog box is thus (Innovmetric, 2007):

1. Max. point-to-plane distance: The distance is related to the density of points in the point cloud. For example, for a close-range scan with a resolution of 0.001 or 0.004 m, the distance should be in the range of 0.004 to 0.016 m.
2. Sampling step: This value should be larger than the standard deviation of the data points, typically at least 3 times larger. For example, for Ilris 3D laser scanner with a standard deviation of 0.008 m, the sampling step

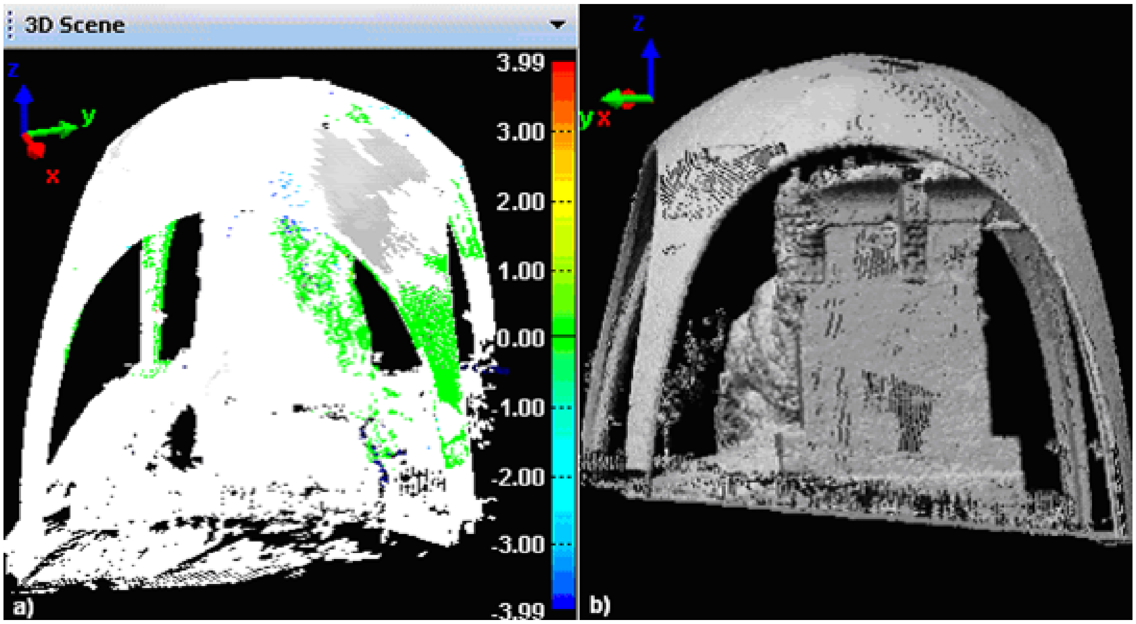

Figure 2(a). Registration error, (b) Point cloud visualization.

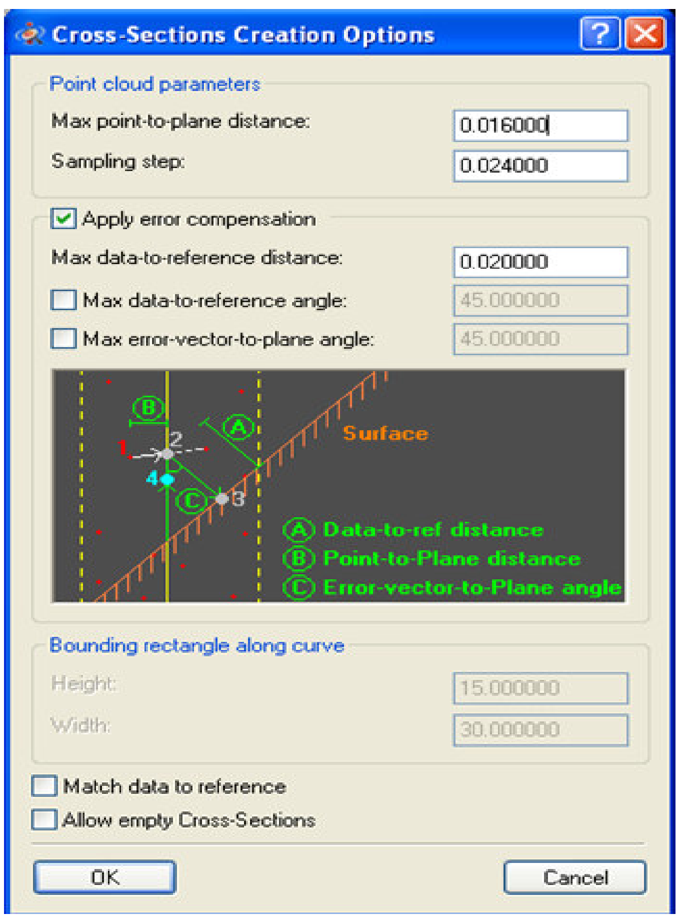

Figure 3. A parameter dialog box that controls the cross-section creation options in Polyworks.

Table 1. Thicknesses from cross-sections in blue, red, green line directions with 3 m intervals.

Cross-sections	Thickness (m)		
	Blue line	**Red line**	**Green line**
a1	0.2199	0.1929	0.1658
a2	0.3116	0.1874	0.2687
a3	0.1950	0.2493	0.2401
a4	0.2939	0.2335	0.2684
a5	0.2894	0.2208	0.3083
a6	0.2543	0.2258	0.2073
a7	0.1128	0.2647	0.2057
a8	0.1820	0.1997	0.1118
a9	0.2415	0.1424	0.3358
a10	0.2888	0.1134	0.3342
a11	0.1720	0.1115	0.3330
a12	0.1120	0.1537	0.2818
a13	0.2066	0.1421	0.2991

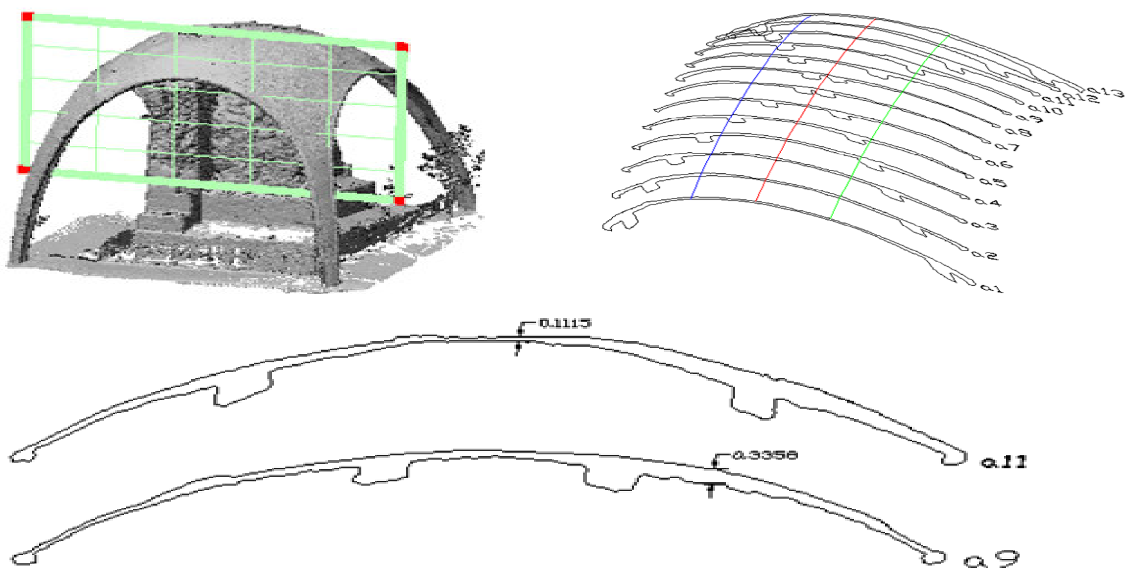

Figure 4. Cross-sections from 3D point cloud model.

should be at least 0.024 m. When the value is larger, noise in the data points is better smoothed.

The sampling step item is irrelevant when the Apply error compensation check box is set.

3. Max. data-to-reference distance: The Max. data-to-reference distance controls the maximum deviation between a data point and a reference surface.

4. Max. data-to-reference angle: As a complement to the first maximum distance parameter, the check box also offers an optional maximum angle parameter. This angle parameter is useful for thin walls, to ensure that top points are matched to the top surface and bottom points are matched to the bottom surface. The Polyworks software checks that the data points have an orientation compatible to their matching reference points before stopping its search.

5. Max. error-vector-to-plane angle: Finally, an additional angle parameter has been added to make sure that the slicing plane does not make a too steep angle with respect to the reference surface.

After the cross-sections were created, they were exported in Autocad dxf file format. The wall thicknesses were measured from cross-sections (Table 1) in Autocad with 3 m interval on three (blue, red, green) directions (Figure 4). While thicknesses are small in some regions due to the break out from the body, it is big in some regions due to the deformation of the top layer of the building. The smallest and biggest thicknesses were measured as 0.1115 and 0.3358 m, respectively (Figure 4).

Conclusion

In this study, 3D modeling of concrete building that was built to protect historical Alaaddin Palace was performed by laser scanning method and measured wall thickness of them from cross-sections. We measured wall thickness from cross-section in three lines. The smallest and biggest thicknesses were measured 11.15 cm and 33.58 cm respectively. Eventually, it can be said that there is no significant change in the thickness of concrete. In this study, all processes have been completed in two days. Not only cross-section but also, all geometrical information can be extracted from 3D laser scanning data. Thinking applicability and benefits of the method, it can be applied to similar aims in civil engineering, architecture and restoration of heritage.

REFERENCES

Al-Manasir K, Fraser CS (2006). Registration of Terrestrial Laser Scanner Data Using Imagery, The Photogrammetric Record, 21(115): 255-268.

Besl PJ, McKay ND (1992). A Method for Resgistration of 3D Shapes, IEEE Transaction on Pattern Analysis and Machine Intelligence, 14(2): 239-256.

Boehler W, Boards VM, Marbs A (2003). Investigating Laser Scanner Accuracy, Proceedings of XVIIIth CIPA International Symposium 30 Sep-4 Oct, Antalya Turkey, 696-701.

Chen Y, Medioni G (1992). Object Modeling by Registration of Multiple Range Images, Image and Vision Computing, 10(3): 145-155.

El-Hakim SF, Beraldin JA, Picard M, Godin G (2004). Detailed 3D Reconstruction Large-Scale Heritage Sites with Integrated Techniques, IEEE Comput. Graphics Appl., 24(3): 21-29.

Gonslia R, Lindenbergh R, Pfeifer N (2006). Deformation Analysis of a Bored Tunnel By Means of Terrestrial Laser Scanning, the ISPRS International Archives of Photogrammetry, Remote Sensing and Spatial Information Science, 36(5), Dresden Germany, pp. 67-172.

Gruen A, Akca D (2005). Least Squares 3D Surface and Curve Matching, ISPRS J. Photogrammetry Remote Sens., 59(2005): 151-174.

Innovmetric (2007). PolyWorks V10 Beginner's Guide, Innovmetric Software Inc., 2014 Cyrille-Duquet, Suite 310, Quebec Canada.

Johansson M (2002). Explorations into the Behavior of Three Different High-Resolution Ground-Based Laser Scanners in the Built Environment, Proceedings of the CIPA WG6 Int. Workshop on scanning for cultural heritage recording, Antalya, pp. 33-38.

Pfeifer N, Briese C (2007). Geometrical Aspects of Airborn Laser Scanning and Terrestrial Laser Scanning, International Archives of Photogrammetry and Remote Sensing (IAPRS). 36(3/W52), Espoo Finland, pp. 311-319.

Scaioni M (2002). Independent Model Triangulation of Terrestrial Laser Scanner Data, The ISPRS International Archives of Photogrammetry, Remote Sen. Spatial Inf. Sci., 34(5/W12): 308-313.

Scaioni M (2005). Direct Georeferencing of TLS in Surveying of Complex Sites, The ISPRS International Archives of Photogrammetry, Remote Sens. Spatial Inf. Sci., 36(5/W17), Venice, Italy: pp. on CD.

Veinhaus FM, Devarajan V (1997). Texture Mapping 3D Models of Real-World Scenes, ACM Computing Surveys, 29(4): 325-365.

Yastikli N (2007). Documentation of Cultural Heritage Using Digital Photogrammetry and Laser Scanning, J. Cultural Heritage, 8(4): 423-427.

Zhang Z (1994). Iterative Point Matching for Registration of Free Form Curves and Surfaces, Int. J. Comput Vision, 13: 119-152.