Australian Journal of Basic and Applied Sciences, 5(5): 1080-1085, 2011
ISSN 1991-8178

A New Approach for Façade Documentation Using Laser Scanner

[1]Ahmed K. Abdel-Gawwad and [2]Yasser M. El-Sherbiny

[1,2]Civil & Architectural Engineering Department, Engineering Research Division, National research center, Dokky, Egypt.

Abstract: Obtaining an architectural complex model requires sophisticated instruments and model surveying. In architecture documentation, choosing the appropriate technology (sensors, hardware, and software), the appropriate procedures, designing the workflow and assuring that the final output is in accordance with the set of technical specifications is always a challenging matter. 3D Laser modeling allows the use and implementation of realistic modeling techniques which is totally different from the traditional modeling approach. Although, these traditional approaches are time consuming and difficult to carry out in the field, the survey of architecture facades to obtain three dimensional models is a must in cases of maintenance, restoration, etc. On the other hand, the rapid progress in obtaining three dimensional coordinates of a mesh of points using laser scanner is a new technique for architecture facades documentation. So, the main objective of the current research is to study the practical feasibility, applicability, and accuracy of using laser scanner in 3D surveying and documentation of architecture facades. To achieve the above mentioned goal, a field experiment is made to practically survey and document an architecture facade. The results showed the success of the proposed technique in survey and documentation of the architecture facades, and its practicality and applicability with high accuracy.

Key words: Architecture facades, Architecture Documentation, Laser scanner, Historical documentation, Laser Scanner accuracy

INTRODUCTION

In the last few years the problem of conservation and enhancement of the Architecture facades, became a great challenge, leading to the development of new technologies and methodologies which allows more efficient, and less time consuming for architectural facades to be surveyed and documented (Patias *et al.*, 2008). Architecture facades surveys are carried out for various reasons such as validation, maintenance or facility management, alterations and additions, restoration, or simply recording of the model and its details (Heuvel, 2004; Burchardt and Voss, 2004). Usually drawings are presented as elevation drawings (2D drawings). However, if laser scanner is used for facade recordings, 3D drawings can be produced with comprehensive details in less time with less effort.

It is well known that documentation and producing of elevations (2D drawings) of architecture facades can be done using traditional surveying techniques, as well as by using laser scanners. The traditional surveying techniques includes mainly joint method, and direct observation using total station with paper prism or prism-less, or the photogrammetric techniques. The major advantages of laser scanning are that the process is a non-contact, fast, and results in coordinate locations that lie directly on the surface of the scanned object which allows delicate parts to be measured and makes the scanned coordinate locations useful in CAD/CAM.

The laser's high resolution and thin beam also allows scanning of highly detailed objects, where other techniques may not accomplish the task of electronic archiving of physical objects. The advantage of laser scanner technique compared to traditional techniques is also the higher degree of details (3D Model) which can be obtained in less time with less effort. Therefore, the present study concentrates on the accuracy and practicability of using laser scanner technique in 3D survey and documentation of architecture facades.

The features of using laser scanner technique in 3D surveying of architecture facades instead of traditional surveying techniques are:

- Fieldwork is minimum and fast.
- Repetition of measurements is easy.
- A permanent record is taken of a very large number of target points.

Corresponding Author: Ahmed K. Abdel-Gawwad, Civil & Architectural Engineering Department, Engineering Research Division, National research center, Dokky, Egypt

- There is no physical contact with the objects, i.e. no necessity to occupy the target point.
- Point coordinate measurements with a high degree of accuracy can be obtained.
- More flexibility in the choice of points to be measured on the recorded image.
- High resolution and high accuracy
- Compact and easy to use
- Easily hand-carried and deployed by a single operator

According to the above discussion, laser scanner method provides information at a very large number of points at the same epoch. Also, the processing of digital model is faster and easier than processing of printed model. Consequently, the main objective of this paper is to asses the accuracy of using laser scanner for documentation, 3D surveying and producing 3D drawings of architecture facades. On other words, the main interest here would be oriented towards the practicality and feasibility as well as the achieved accuracy of this technique, based on actual field experimental data. If this objective is verified, the proposed technique could manifest itself to totally replace the teddies traditional surveying techniques for detailed surveying of architecture facades proving that this modern technology can provide highly valuable elements of solution for monitoring and preservation.

Historical urban documentation:

One of the important issues facing planning is how to provide room for the growing in the number of households, how to regenerate cities and how to create more sustainable urban areas. If we study the past and learn from it, we need to know how cities have been able to adapt and to accept changes (Ford, R.L., 1978). If a city is to keep its entire heritage, changing becomes impossible, on the Contrary if a city losses all its past, it may lose its bond with its heritage. Recording of historical areas is essential for regenerating the urban environment, especially when important features of the area are lost or seriously damaged.

The use of laser scanners for the documentation of historical buildings makes it easy because of the acquired large quantities of data in a short period of time. In the past few years laser scanner became an attractive method in this field yet, it depends on the model structure and cost issues. Cultural heritage documentation is more challenging and varying due to the models size and requirements. In some cases models were not accessible or too large and complicated. Quite often the surroundings were too complicated or unsuitable for taking measurements, while in less often events the models were in danger of environmental factors. Furthermore in some cases the model has lost a great deal and only a small part was left from the original.

Investigation methodology:

The application of this research paper is performed on one of facade of the faculty of Engineering, Ain Shams University, Cairo, Egypt, see figure (1). Recalling that, laser scanning is the science and art of taking three dimensional coordinates of objects in a pre-specified ground coordinate system. Thus, the surveying of this architecture facade will be based on the following procedure:

- Fixing of paper prism points on the facade.
- Surveying the paper prisms using total station to obtain the 3D coordinates of the fixed points in a pre-specified ground coordinate system, to obtain 3D coordinates of the paper prism points.
- Surveying the facade using laser scanner technique with scan density of 1 cm * 1 cm and densifying it to 1 mm * 1 mm at the paper prism position, to obtain 3D model of the facade as well as accurate 3D coordinates of the paper prism points.
- Accuracy assessment of the developed 3D model, using the coordinates of the fixed paper prism.
- Architecture documentation and recording of the 3D surveyed architecture facade.

Such operations will be briefly discussed in the subsequent sections, as far as the experiment of the proposed technique as applied to detailed surveying of architecture facades.

Overview of scanstation 2 laser scanning system:

3D Scanning System consists of a ScanStation 2 scanner, figure (2), a laptop and Cyclone Software. The ScanStation 2 captures 3D surface geometry of complex structures and sites with an unprecedented combination of completeness, speed, accuracy, and safety. The specifications of Leica Scan Station 2 are as shown in Table (1). Simply set the scanner on a tripod, select the desired measurement area and scanning density, and then scan. Complete surface geometry of exposed surfaces is remotely captured in minutes in the form of dense, accurate 3D point clouds, ready for immediate use.

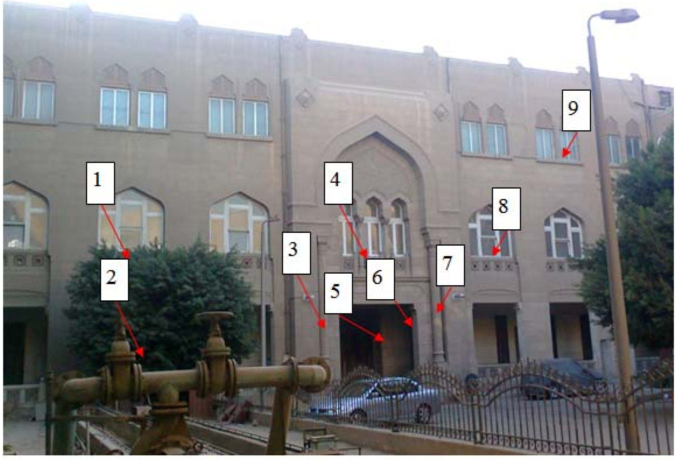

Fig. 1: Shows the used architecture façade as well as the position of the fixed paper prism.

As soon as ScanStation 2 has scanned a structure or site, Cyclone software lets you use the 3D point clouds for a wide variety of applications, including those requiring export to CAD and rendering software. ScanStation 2 can provide significant cost savings in many ways:

- Lower cost as-built & topographic surveys vs. alternatives
- Limiting or eliminating return visits to the site
- More accurate, complete surveys
- In addition to direct cost savings, ScanStation 2 offers important added value benefits:
- Shorter project cycle times
- Better quality results
- Improved safety during data capture
- Unobtrusive data capture
- Point clouds can be conveniently used & reviewed by others for more efficient management of projects

Fig. 2: Leica Scan Station 2

Table 1: The specifications of Leica Scan Station 2

Instrument type	Pulsed, dual-axis compensated, very-high speed laser scanner, with survey- grade accuracy, range, and field-of-view	
User interface	Notebook or Tablet PC	
Camera	Integrated high-resolution digital camera	
Accuracy of single measurement	Position*	6 mm
	Distance*	4 mm
	Angle (horizontal/vertical)	60 µrad/60 µrad (3.8 mgon/3.8 mgon)
Laser spot size	From 0 – 50 m: 4 mm (FWHH-based); 6 mm (Gaussian-based)	
Modeled surface precision/noise	2 mm	

Table 1: Continue

Target acquisition	2 mm std. deviation	
Dual-axis compensator	Resolution 1 ", dynamic range +/- 5	
Data integrity monitoring	Periodic self-check during operation and start-up	
	Range	300 m @ 90 %; 134 m @18 % albedo
	Scan rate	
		Maximum instantaneous: up to 50,000 points/sec
Laser scanning system	Scan density	Average: dependent on specific scan density and field-of-view
		<1 mm max, through full range; fully selectable horizontal and vertical spacing; single point dwell capability
Laser class	3R (IEC-60825-1), visible green	
Lighting	Fully operational between bright sunlight and complete darkness	
Power supply	36 V; AC or DC; hot swappable	

Field experiment and measurements:

To test the accuracy, reliability and applicability of using laser scanner in 3D surveying and recording of artificial facades, a facade with complex details was selected. First, a coordinate system was established. In this coordinate system the facade features are in the X and Z axis, while the Y axis is perpendicular to the facade features. Nine paper prisms were fixed on the facade, see figure (1). The coordinate of the paper prism points were measured using a total station (Topcon GTS702) with a measuring accuracy of 2" in angles and 2 mm in distances. The coordinates obtained for the 9 points are listed in table (2).

Table 2: the coordinates of paper prism points fixed at the facade using total station.

Point	X (m)	Y (m)	Z (m)
1	2010.911	4013.993	106.334
2	2010.907	4013.988	101.216
3	2003.99	4013.613	102.8905
4	1999.781	4014.688	106.561
5	1998.044	4018.629	102.2435
6	1997.79	4014.613	102.964
7	1996.907	4014.147	102.8405
8	1993.334	4015.113	106.394
9	1988.896	4015.081	111.838

Second, the facade was scanned using a Leica Scan Station 2, as a data capturing device see figure (2). The facade was scanned with a scanning density of 1 cm * 1 cm. Densifying the scan at the paper prism areas to 1 mm * 1 mm. The coordinates of the paper prism points was measured on the processed program. Table (3) shows the coordinates of the fixed paper prism points on the facade using laser scanner. Figure (3) shows the 3D model (point cloud model) of the survey facade after transforming the model from the software of capturing data to the AUTOCAD software environment.

Table 3: The coordinates of the fixed paper prism points at the facade using laser scanner.

Point	x	y	z
1	2010.910	4013.993	106.334
2	2010.911	4014.000	101.216
3	2003.974	4013.627	102.902
4	1999.775	4014.660	106.558
5	1998.058	4018.631	102.247
6	1997.778	4014.581	102.952
7	1996.895	4014.136	102.834
8	1993.351	4015.084	106.384
9	1988.896	4015.081	111.838

Test results and analysis:

Starting by testing the accuracy of surveyed three dimensional model of the facade, discrepancies of coordinates and spatial distance are computed. This has been done by subtracting the coordinateness of paper prisms points obtained by laser scanner from the coordinates obtained by total station. These discrepancies are calculated in X, Y and Z directions as well as in Position. Table (4) shows the discrepancies as well as their statistics calculations (Maximum, Minimum, Mean, and Route Mean Square Error). Furthermore, the discrepancies in distances between paper prism points are computed in Table (5).

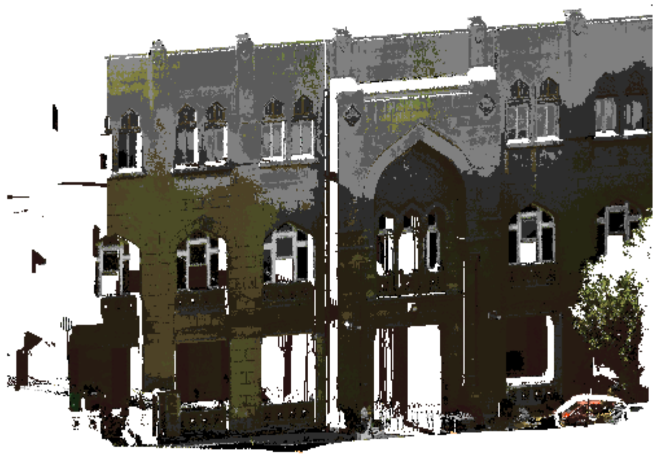

Fig. 3: Shows the 3D model (point cloud model) of the survey facade on the AUTOCAD software environment.

Table 4: The discrepancy of points between total station technique and laser scanner technique in X, Y, Z, and P.

Point	ΔX (mm)	ΔY(mm)	ΔZ (mm)	ΔP (mm)
1.0	-1.0	-8.0	-2.0	8.3
2.0	-5.5	-19.9	-2.0	20.8
3.0	15.4	-22.1	-13.5	30.2
4.0	4.7	20.3	1.0	20.9
5.0	-14.9	-9.9	-5.5	18.7
6.0	10.6	24.5	10.0	28.5
7.0	11.1	2.7	4.5	12.3
8.0	-18.2	20.6	8.0	28.7
9.0	-1.0	-8.0	-2.0	8.3
Max	15.4	32.5	12.0	13.0
Min	-18.2	-22.1	-13.5	8.3
Mean	0.1	0.0	-0.2	19.6
RMS	11.0	16.9	6.7	18.4

Table 5: The discrepancy between total station technique and laser scanner technique.

Line		Total Station Technique	Laser Scanner Technique	Discrepancy
From	To	L (m)	L (m)	ΔL (mm)
1	2	5.118	5.118	0.0
2	3	7.127	7.150	-22.9
3	4	5.687	5.662	25.2
4	5	6.098	6.108	-9.4
5	6	4.088	4.121	-32.7
6	7	1.006	0.996	10.1
7	8	5.131	5.105	26.2
8	9	7.024	7.042	-18.6
9	1	22.718	22.718	0.0
		Max		26.2
		Min		-32.7
		Mean		-2.5
		RMS		19.6

Knowing that, the accuracy of point position using total station with fixed paper prism is in the range of fractions of a millimeter (Abdel-Gawad *et al*, 2007). the examination of tables (4) and (5) reveals that:

1- The accuracy of point position (3D) surveyed by laser scanner are 11 mm in X-direction (horizontal direction of the facade), and 7 mm in Z-direction (vertical direction of the facade, and 17 mm in Y-direction (perpendicular to the facade's direction) as well as 18 mm in space position.

2- The accuracy of spatial distances is 20 mm.

Conclusion:

The obtained results indicate that, the 3D survey of architectural heritage using laser scanner technique can be practically applied on architecture facades with less cost and constrains than the traditional surveying techniques, in cases where the expected accuracy to be in the order of about 2 cm in position and distance. The study also reviled that the obtained data could be used in a wide variety of applications supporting different activities and fields. The results also show that laser scanner could be used not only in documentation of the façade, but also the surrounding urban area with all its features which makes it comparative to the use of photogramemtry in this field.

REFERENCES

Abdel-Gawad, A. K., M. El-Tokhey and K. Abdel-Mageed, 2007, "Integration Between Surveying And Electro-Mechanical Techniques In Monitoring Deformations Of Monuments Case Study: Luxor and Karnak Temples", Scientific Bulletin of the Faculty of Engineering, Ain Shams University, 42(4) Cairo, Egypt,

Boehler, W., 2003, "Comparing different laser scanners: features, resolution, accuracy", In CISM, International Centre for Mechanical Sciences, Udine.

Burchardt, C.B. and K. Voss, 2004 “Façade Reconstruction of Destroyed Building Using Historical Photographs", Congress, 12-23, Istanbul, Turkey.

Ford, R., L., 1978, "Continuity and Change in Historic Cities: Bath, Chester and Norwich. Eographical Review", JSTOR 68(3).

Heath, T., 2001. "Revitalizing Cities: Attitudes toward City-Center Living in the United Kingdom", Journal of Planning Education and Research, 20: 464.

Heuvel, F.A., 2004, “Reconstruction from a single architectural image from the meydenbauer Archieves”, ISPRS Congress, 12-23 July 2004 Istanbul, Turkey.

Jamieson, W., 2009. "Recording the Historic Urban Environment: A New Challenge", APT Bulletin, 22, Cultural Resource Recording.

Leica Scan Station 2 Manual, 2008.

Patias, P., P. Grussenmeyer, K. Hanke, 2008. "Applications in Cultural Heritage Documentation", ISPRS 2008 Congress Book. Ed. CRC Press, Taylor and Francis Group.

Topcon Total Station GTS702 Manual, 2004.