Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (43) No . (3) July . 2021

Terrestrial Laser Scanning for Heritage Conservation: Amr Ibn Al-Aas Islamic Mosque, Cairo, Egypt, Case Study .

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الملخص العربى :

يصبح الحفظ الرقمي للآثار التاريخية باستخدام تقنيات القياس ثلاثية الأبعاد المتقدمة أداة محتملة وفعالة لرسم الخرائط. بالإضافة إلى الأساليب التقليدية مثل القياس اليدوي البسيط وقياس سرعة الدوران، أصبح المسح بالليزر ثلاثي الأبعاد للأرض سريعا أحد أكثر التقنيات شيوعا نظرا لاكتماله ودقته وثباته.
يقيم هذا البحث قدرة تقنية المسح بالليزر الأرضي لتوثيق بيانات واجهة النصب التاريخية في بيئة ثلاثية الأبعاد. ثم يتبع ذلك إنشاء نموذج مرئي ثلاثي الأبعاد بناء على سحب النقاط الملونة المسجلة. في هذا المشروع ، دورة كاملة لحفظ التراث ، بما في ذلك: الحصول على البيانات ، ومعالجة بيانات السحب النقطية الناتجة عن المسح بالليزر الأرضي (Leica P30) ، بالإضافة إلى تقنيات مختلفة لبرامج الإخراج ثلاثية الأبعاد (Cyclone و True View و Jet Stream) ، بناء على الخبرات المكتسبة أثناء توثيق المواقع التراثية لمسجد عمرو بن العاص. كما يتم عرض التنسيقات المتاحة لتصدير بيانات الإخراج إلى مختلف المستخدمين.
تم تسجيل عدد كبير من عمليات المسح الفردية للمباني وملاجئ الصخور والمناظر الطبيعية وأظهرت مزايا المسح بالليزر مقارنة بالطرق الأخرى ، ولكنها كشفت أيضا عن التحديات التي يجب معالجتها لتطوير الإمكانات الكاملة للمسح بالليزر. يتم الإبلاغ عن تجارب العمل الميداني (المسح الأرضي) ، وتسجيل المسح ، وملء الثقوب ، وتنظيف البيانات ، والنمذجة ، والتركيب ، بالإضافة إلى خيارات العرض ومناقشتها بإيجاز.

Abstract:

Digital documentation of historical structures of ancient cultures utilizing progressive 3-D quantification technologies turn into a prospect and functional system for mapping solution. Unlike classic surveying techniques , 3-D terrestrial laser scanning is speedily became one of the most appropriate methods because of its integrity, reliability and stability features.

Current research assesses the potentiality of terrestrial laser scanning technology for recording the ancient cultures information in 3-D surroundings. After that, 3-D model using recorded colorized point clouds, was generated. Through current research, a complete cycle for Heritage Conservation, including: data acquisition, data processing of point clouds produced from terrestrial laser scanning (Leica P30), as well as different 3D output software techniques (Cyclone, True View, and Jet Stream), according knowledge obtained whereas documenting for the Amr Eben Aaas Mosque. Also, the available formats for exporting output data to various users are presented.

Large number of individual scans of buildings, rock shelters and landscapes were registered and the study showed that the description of things using laser scanner differs from classic techniques. However, some difficulties, are required to be guided to promote the full capacity of laser scanning. Practicing gained from fieldwork (ground surveying), i.e. "scan registration", "hole-filling", "data cleaning", "modelling", and "texturing", in addition to visualization preferences are stated and discussed shortly.

Keywords:

3 D Terrestrial laser scanning - Heritage Conservation - Amr Eben Aaas Islamic Mosque.

1- Introduction:

Considerably, documentation of historical structures assists for education new staff working within history incidents. Moreover, historical monument is considered patrimonial from predecessors **(Prentice, 1993)**. Those old humans award us ultimate developed techniques, familiarity and people's life manner in each phase of human history. Consequently, endeavor for study and imagine of ancient structures and scenes became of high preference. Protecting ancient structures and scenes is significant matter because of its high historic significance. Those structures were at risk of erosion, destruction, and unique artefacts, that gone over considerable phases of building, destruction and restore. So, it is significant to quantify and model these structures with high perfection.

Recently, Terrestrial Laser Scanner" (TLS) as well as photogrammetry, are very efficient procedures for acquisition 3-D data and appearance of the structure with minimum interaction with the structure. Produced point clouds from TLS is textured utilizing high-quality images obtained from different new digital cameras. Colored point clouds are used to generate various sections such as: "top", "front", "back", "left", "right" and finally, drawings are produced through any CAD software package. Generally, 3-D digital documentation is adequate for structure reconstruction, especially in case of damage occurring **(Kushwaha, et al, 2020)**.

Because of complication of these structures, 3-D generated models as well as its visualization is time consuming and strenuous, which requiring a lot of processing effort. Attaining this tactic, digital 3-D terrestrial laser scanning method adventure is utilized to minimize the time of visualization. 3-D laser scanning applied for re-building and maintenance of ancient structures and sites, is mostly agreeable within surveying society because of its extraordinary characteristics **(Sgrenzaroli, 2005)**.

Recently, it seems to be that usage of 3-D terrestrial laser scanning was increased due to its validity for registration and documentation of heritages. The reason behind is the ability to give different users with preferable spatial data of complex structures within short period of time. Another benefit is that actual scene for the structures by merging colors with point clouds, which led to interactive navigation (third dimension) around and through the object. Additionally, "TLS" method provides superior useful data collection especially in non-reachable places **(Wei, et al, 2010)**.

Many regarding jobs have demonstrated that "terrestrial laser scanning" is a robust tool concerning: registration of objects and sites; and scientific research applications. **Ruther, et al (2009)** stated through a research work that using rigorous 3-D model of the heritage objects can affect on both: aesthetic and functional implications of future work to restore and conservate ancient objects. So, such digital documentation of ancient objects is an essential reference for future generations and restoration procedure. Classical 3-D modelling tools are generally incomplete for heritage applications due to shape complexity and high accuracy required **(Fontana, et al., 2002)**.

Bohm, (2009) reviews the past efforts in terrestrial data acquisition, gives an outline of the present techniques, processing procedures, modeling approaches (specifically the modeling problem using terrestrial data for urban areas for creating different types of facades) and future topics in automated indoor modeling. **Becker and Fritsch (2010)**, demonstrate the Combined Knowledge Propagation Algorithm for 3-D Urban Models and 3-D Building Representations. This Algorithm was found to be flexible to be used in different scenarios:

- Facade captured with accurate and dense sensor data;
- Facade captured with inaccurate, noisy or incomplete sensor data; and
- Facades not covered by any sensor data.

Terrestrial laser scanning represents a primary function in acquiring 3-D integral data for city modeling; particularly the increasing request for detailed façade models required for developments to restore and document during any disaster projects.

Therefore, and to cope with day-to-day applications and projects for urban growing in Egypt, the current research will focus on training and using terrestrial LiDAR, as well as the accompanying software packages, for Amr Eben el-Ass Mosque, Cairo, Egypt . First step is to geo-referencing the site to the national geodetic network of Egypt. After that, 2-D model for Facades and 3-D models for the Monument will be created and accuracy assessment will be done. More over a go through trip will be generated for any monumental building.

2- Study Case:

The location of study area was chosen to be the archaeological site, namely: Amr Ibn Al-Aas mosque in Old Cairo (Figure-1).

3- Methodological Approach:

The following sub-items was executed depending on the available permissions and circumstance
es during the field trip:

1- Survey Planning:
- Determine the goals and objectives;
- Analyzing the object or area to be surveyed;
- Determine optimal scanning locations;
- Determining the optimal target locations; and
- Data management.

2- Field operation:
- Survey preparation;
- GPS network execution;
- Setting up the scanner;
- Connecting the scanner; and
- Scanner settings.

3- Data acquisition:
- Scanning the object / building;
- Scanning targets;
- Measuring the targets; and
- Completeness checking.

4- Data preparation.

5- Registration & Geo-referencing:
- Indirect Registration & Geo-Referencing; and
- Direct Registration & Geo-Referencing.

6- 3D point cloud processing:
- Point Cloud representations;
- Data improvement;
- Direct 3D modeling from point clouds;
- 3D modeling of complex surfaces; and
- Texture mapping.

7- Quality control & Delivery.

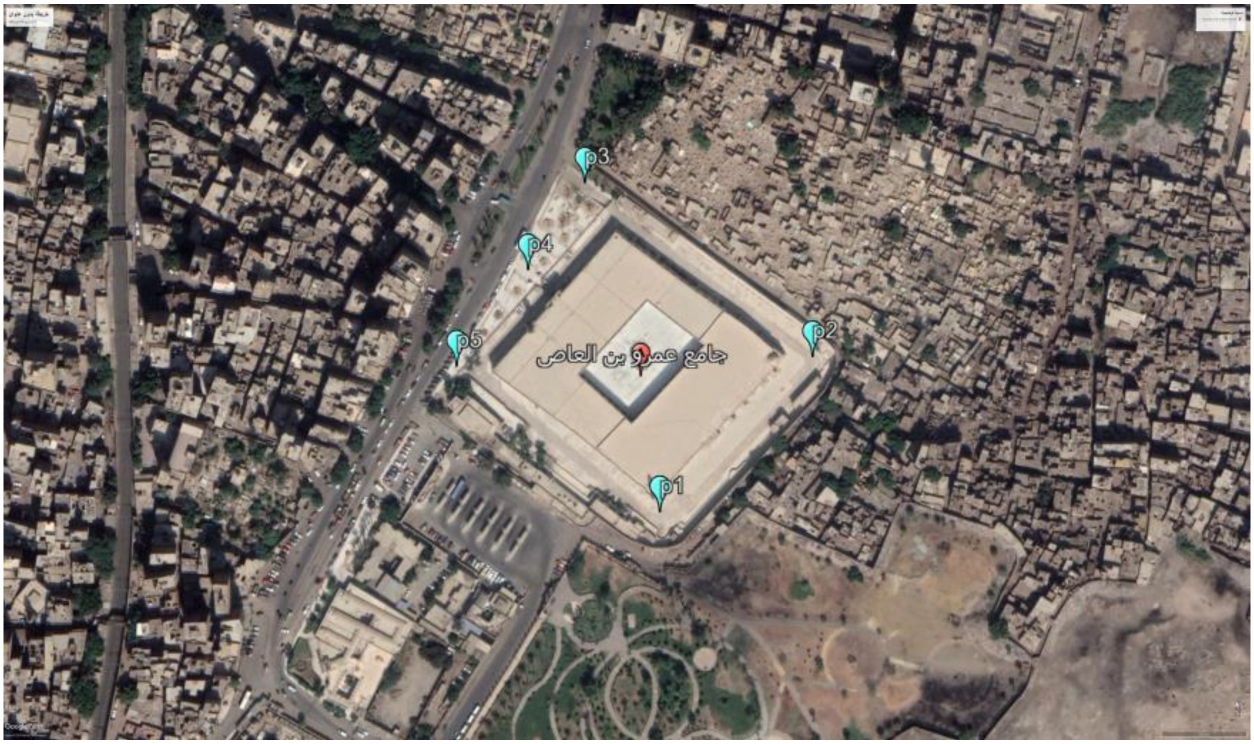


Figure -1 Location of Amr Ibn Al-Aas mosque in (Old Cairo) and Ground Control Points around it.

4- Experimental Procedure:

The study area was investigated.
A permission was given from Supreme Council of Antiquity to Perform the required documentation of Amr Ibn Al-Aas Mosque.
Selection and Executing the ground control points using GPS around the mosque.
The GPS Points observed using GPS Leica (GS-15),in WGS-84 and UTM projection .
The ground stations are determined and well distributed inside and outside the monument.
The data was collected from forty two occupied stations by the Terrestrial Laser Scanner (P30).
All the data from the occupied stations was georeferenced using the Cyclone software **(Leica, 2021)**.
Then the required façade was produced by using Cyclone.
A True View software package (free viewer from Leica) is used to facilitate taking measurements from photos only.
Jet-Stream software package (free viewer from Leica) is used to facilitate taking measurements from point clouds and photos simultaneously.
A data base created for the Amr Ibn Al-Ass Mosque, including: pieces; photos and meshes for all objects.

All products for the project were exported and delivered in different formats to help in different cases such as virtual reality and augmented reality.

GIS layers from the produced data is proposed to be produced .

5- Results:

For using Terrestrial Laser Scanner on the archaeological site, namely was used for Amr Ibn Al-Aas mosque in the ancient region of Cairo. Different results summarized as follows:

- Main GPS network was fixed; measured and adjusted around the site (Figure-2 and Table-1);
- Secondary network inside the building was set; measured and adjusted using Total Station or the laser scanner itself;
- The suitable scan stations required to cover all the project were selected , fixed and georeferenced (Figure-3a , 3b).
- Scan all possible facades and constructions outdoor and indoor;
- Geo-referencing all the scans together using Leica Cyclone Software Package.
- Figure-4 and Figure-5, as an example, show a snapshot from point cloud covering different objects appeared in the project (e.g. facades – disks – floors – doors - ….etc).

Figure-2 Main GPS network for Amr Ibn Al-Aas mosque in Old Cairo

Table-1

Coordinates of Main GPS Network Points (WGS-84/UTM)
for Amr Ibn Al-Aas Mosque in the Ancient Region of Egypt (Old Cairo)

Point ID		Easting	Northing
p1	329605.7181	3321134.018	
p2	329694.028	3321224.592	
p3	329559.961	3321325.178	
p4	329527.4901	3321273.571	
p5	329486.8221	3321216.862	

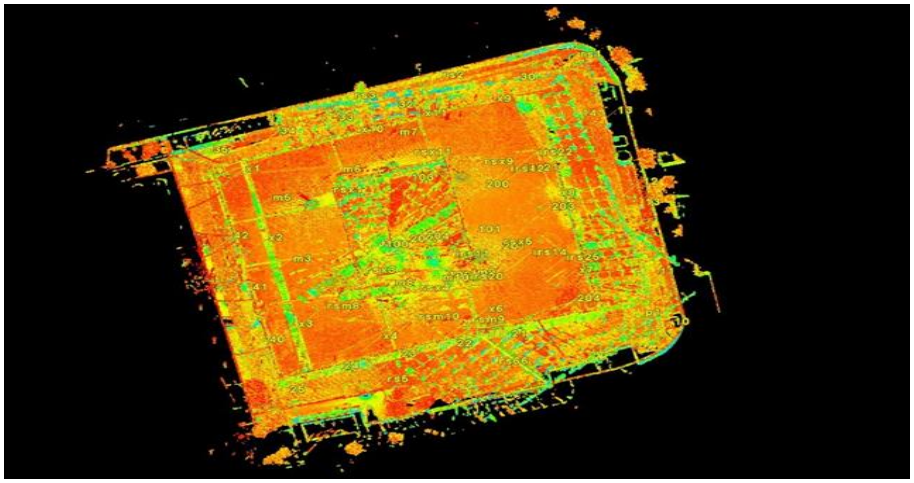


Figure 3-a point cloud for Amr ebn al- ass mosque captured from 42 occupied stations .
File size (300 G.B. before cleaning – 279 G.B. after cleaning)

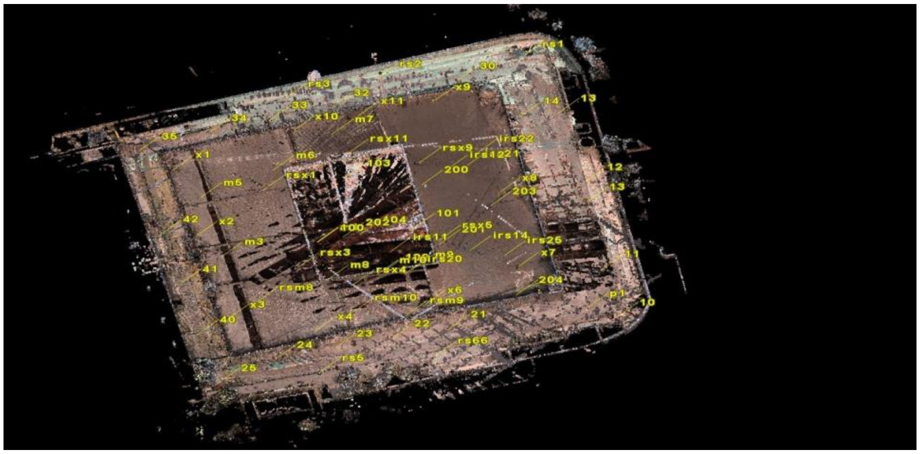
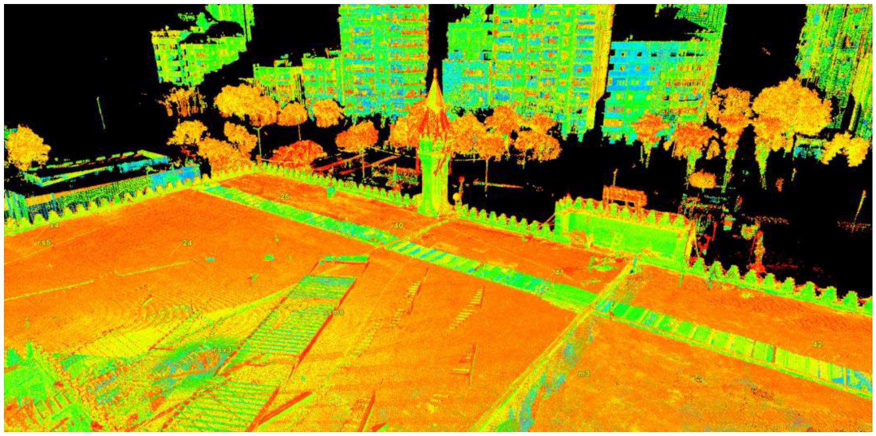


Figure-3-b

Snapshots for the Project Plane Explaining Positions of Scan Stations
for Amr Ibn Al-Aas mosque in the ancient region of Egypt Old Cairo.(key plane).



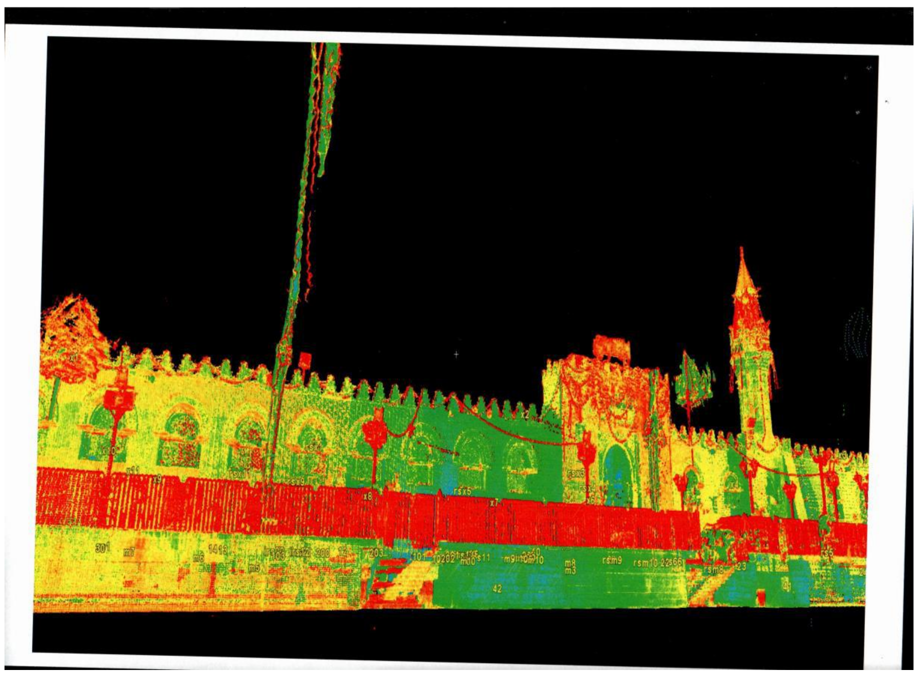


Figure-4 Snapshot from Point Cloud Scans of Different Objects
r Amr Ibn Al-Aas mosque in Old Cairo.

Figure-5 Snapshot from Point Cloud Scans of Different Objects
for Amr Ibn Al-Aas mosque in Old Cairo.
(True view – LGS. Files)

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