

Low Cost Handheld 3D Scanning for Egyptian Architectural Artifacts Acquisition

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Abstract: Surface reconstruction of objects using photogrammetry and terrestrial laser scanning systems (TLS) has been a topic for research for many decades, especially for culture heritage data recording. Recently, many advances into these systems are now available in the market, which give the availability of collecting a huge number of geo-referenced 3-D points covering any object surface. Due to speed and efficiency of data acquisition by means of terrestrial laser scanners, researchers and designers can select the reliable technique, depending on their application, that can be complete to give good results for the complex surfaces such as heritage objects.

As Grand Egyptian Museum (GEM), located nearby the Giza Pyramids, is set to open by 2020, which considered as the largest museum from its type all over the world, with a huge area covered about a half million m². GEM is proposed to be a unique museum all over the world for presenting a huge number from old history Egyptian artifacts.

Consequently, there is a vital need for building a huge digital database containing complete information for this large number of artifacts. Mobile applications are presently at the primacy of documenting historical and archaeological sites. The current paper examine the methodological framework adopted for one high copy of Pharaonic artifacts, namely Offering Carrier, using hand held laser scanning and convert the results to a mobile application.

Keywords: cultural heritage, handheld scanners; laser scanning, Pharaonic artifacts.

I. INTRODUCTION

Reverse Engineering, or back engineering, is the process by which any object is deconstructed to give out its design; architecture; or to extract information from the object's surface. This process became a backbone for many products developments, and consequently, became a remarkable tool in multitude applications such as cultural heritage, car industry and space technology. The process of Reverse Engineering categorized on two main steps: scanning and data processing [4]. The different techniques for scanning generally classified into contact and non-contact methods (Fig. 1). The main purpose of the 3-D scanning is to collect and record object surface particularizing the shape and dimensions either using contact scanners (probes) or non-contact scanners (optical systems).

Using contact scanner means that the probe physically contact the object surface during scanning, while non-contact scanner do not. Non-contact techniques could be: photogrammetry [18], triangulation and time of flight [16], or other light sources such as laser and white light [15].

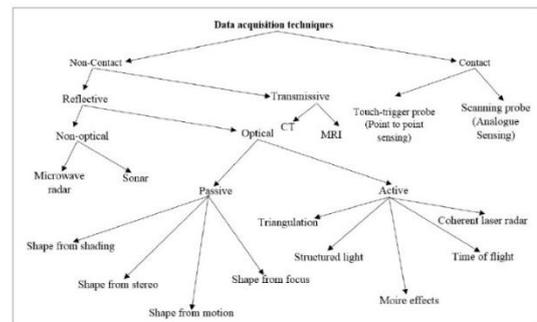


Fig. 1. Different Techniques of Data Acquisition. Note: Computed Tomography (CT) - Magnetic Resonance Imaging (MRI)

Light Detection And Ranging (LiDAR) became a well-settled technique for 3-D acquisition of object surfaces [7]. Recently, airborne LiDAR is used for the Digital Terrain Models (DTM) as well as city modelling production.

On the other hand, Terrestrial Laser Systems (TLS) became popular instruments in the market for many applications, and are available by a multitude number of companies nowadays. [13], mentioned that there are many systems from different manufactures were available in the market. Consequently, laser-scanning technique is one of the methodologies that make 3-D surveying get better and faster. The senior feature of this technique is that assist for complete and detailed 3-D surface acquisition of objects. Accordingly, point clouds produced can be treated to produce 3-D geometric models [3]. Recently, many handheld scanning systems, which have many benefits: low cost, high speed and accurate, have been available for different applications including cultural heritage. Consequently, it is important to exercise, test and explore the characteristics of these systems for 3-D data acquisition, processing and geometric accuracy for different objects [2].

Due to the advantages of 3-D handheld scanners, namely: low weight and great flexibility during either research or industry scanning, they are used for generating accurate 3-D surfaces using triangulation method for light fallen on the object surface and then measuring the distances between the object and the scanner source used [4].

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II. HANDHELD 3-D SCANNING TECHNOLOGY

The 3-D scanners are devices, which are able to collect geometry information about a real-world object or environment. Then this information are processed in order to build digital 3-D models of the scanned elements. Nowadays, 3-D scanning devices play a key role in many research field and applications such as: cultural heritage preservation and documentation, industrial, prosthetics and medicine prototyping, etc. [5]-[12]-[20]-[21]-[22]-[23]-[17]-[8]. Since these devices works by employing many different technologies and their cost change in a wide price range, it is important to select the best solution for your own applications.

As mentioned in section (I) above, the most common technologies employed for 3-D scanning are triangulation. Sensors that exploit these technologies belong to the class of the so-called active sensors. Indeed, these devices “emit” electromagnetic waves on the objects to estimates their geometrical properties. On the other hand, sensors, which do not introduce waves in the environment, called passive sensors. In this latter case, the 3-D acquisition could be achieved for instance by stereo vision or structure from motion [10].

From another perspective, the 3-D scanning devices can be categorized in respect to their portability. In recent years, thanks to the miniaturization and integration of the electronic and optical sensors, has been possible to produce small and compact high performance 3-D scanners [14]-[19]. So, the emerging handheld scanners are a remarkable fortune for affordable price and good performance and the suitability guaranteed by the portability. For relative low-cost and usability, most of these devices became consumer electronics product, while other are still used in professional context. However, they represent a great resource the Cultural heritage applications. Some of these scanners types can be stated as: Kinect (1 & 2); Scanify Fuel 3D; Google Project Tango; Artec Eva and Artec Spider.

Kinect scanner is mainly used in house videogames enjoyment. Cappelletto [9] and Remondino [17] outlined examples from applications using these types of devices related to cultural heritage. Scanify Fuel 3D is a handheld device, which exploits combination of photometric and stereography techniques to acquire depth information, so it can reach a high accuracy. Google Project Tango is a Google device with exploits motion tracking to understand position and orientation of the device user. It is particularly suitable for augmented reality application. Structure Sensor is a small active scanner produced by Occipital. It exploits structured light technology to guarantee a good quality scan with a low expense. Artec Eva and Artec Spider considered as semi-professional scanners manufactured by Artec 3D company. The first one has a high resolution and it is suitable for small and detailed object, while Artec Eva is though for architectural elements such as doors, statue etc. An example of Cultural heritage application can be find in [1].

For data acquisition (scanning) purpose, a new version from handheld scanner based on laser, from type: Artec Leo (Fig. 2) has been employed in the study conducted on current work. Artec Leo scanner use positioning targets for

reference. However, for the current work, no positioning targets for reference are used, considered that the database is in the preliminary stage. Table-I shows some technical specifications for this type of scanners [6].



Fig. 2. Handheld Laser Scanner “Artec Leo” used in Current Work.

Table-I: Some Technical Specifications (Artec Leo) Handheld Scanner

Technical Specification	Leo Scanner
Scanner Type	Handheld
3-D Point Accuracy, up to	0.1mm
3-D Resolution, up to	0.5mm
3-D Accuracy over Distance	0.03% over 100cm
Active Distance	0.35 - 1.2m
Field of view	38.5 x 23°
Texture resolution	2.3mp
Colors	24bpp
Data acquisition speed, up to	3 mln points / sec.
3D exposure time	0.0002 s

III. STUDY CASE

To accomplish the objective of building digital database for a large number of Pharaonic artifacts, which will be moved and presented at Grand Egyptian Museum (GEM), a design of experiment has been employed using one high copy from Pharaonic artifacts, namely: Offering Carrier (shown in Fig. 3). This artifact considered a sculptured wooden statue, belongs to Middle Kingdom, 11th Dynasty.

The Pharaonic artifact used in the current research describes a woman walking on a rectangular base. The Pharaonic artifact carries a basket including four red pitcher that may be likely for wine. The pitcher is sealed with conical cover. The Pharaonic artifact left hand upholding the basket while its right hand holding wings of a duck. The Pharaonic artifact is wearing a long three-part toupee and a long tabard that shows its feet. Its neck is graced with a collar of multiple strings of red, green, and blue beads.

The Pharaonic artifact is barefoot, and its ankles are decorated with two bands. The height dimension of this artifact is 123 cm [11]. However, the height dimension of the artifact copy used in the current work is about 50 cm.



Fig. 3. One copy from Pharaonic artifacts used in Current Work: Offering Carrier.

IV. METHODOLOGICAL APPROACH

Fig. 4 shows the flowchart, which summarizes the scanning procedure using the Artec Leo Handheld scanner through the accompanied software Artec Studio.

V. EXPERIMENTAL PROCEDURE

A. Preparation

The artifact used is cleaned and the light condition is suitable.

B. Scanning Method

Geometry and Texture, which is the suitable scanning for most cases, used for capturing outer surface of the artifact. The number of scans resulted are four scans (Table-II). Fig. 5 shows snapshots from the different frames during the scan process.

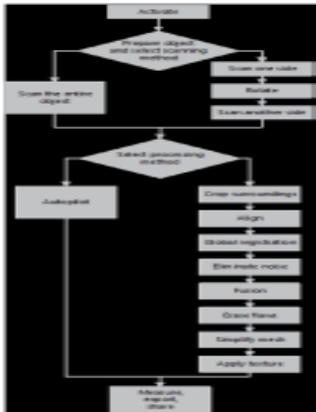


Fig. 4. Flowchart for the Different Logical Steps used in Current Work.

Table-II: Technical Specifications for the files resulted from Scanning the Statue.

Scan No.	No. of Frames	Size of Files
1	2589	2 GB
2	1104	863 MB
3	312	162 MB
4	129	40 B

C. Processing Method

Global registration algorithm, used to convert all single-scan surfaces to a unified coordinate system using information on the alternate position of each surface pair. This process executed by selecting a group of clearly defined geometric points on each single-scan, and then matching between the same points on different scans is calculated.

Max error is the parameter that considers every single-scan registration quality. It shows the maximum value among all the scans. Alignment considered to be accurate if the error magnitude is small. In the current study, this error was between 0.3 to 0.4 μm, which accepted for the study case in hand. In this context, the registration executed first without cleaning the noise (without Outlier Removal). Fig. 6 shows snapshots for the statue after this process.



Fig. 5: Snapshots from the Different Frames during Scan Process.



Fig. 6. Snapshots for the results after Applying "Global Registration Algorithm".

D. Cleaning

1- Apply "Outlier Removal Algorithm" to Remove point clouds that not related to the scanned object (Fusion Menu at Tools). The process takes 776.5 sec. in the current case. The error analysis "Global Root Mean Square Error" for the four scans was: warning; 0.40 μm ; warning and 0.30 μm ; respectively. Warning means not all outliers are removed; i.e. not recognized it's belong to object or not as shown in Fig. 7.



Fig. 7. Snapshots for the results after Applying "Outlier Removal Algorithm".

2- Cleaning the rest of outliers by applying “Editor Algorithm; Eraser function”. Base Selection for the outlier around and beside the object base. Then, press, “Erase”. Then, use “Lasso Selection” to erase the remaining outliers behind the head of the object, as much as needed as shown in Fig. 8.



Fig. 8. Snapshots for the results after Applying “Editor Algorithm; Eraser function” for the Object Base.

3- Merge all scans to identify the holes that must be filled by applying “Sharp Fusion Algorithm” as shown in Fig. 9.



Fig. 9. Snapshots for the results after Applying “Sharp Fusion Algorithm” for Detecting Gaps (Holes) in the Scanned Object.

4- To fill the holes (gaps) in the scan (e.g. for the base and the crown), two steps will be executed. First, applying “Hole Filling Algorithm” to determine accurately the position of the holes through the whole scan. Second, applying “Fix Hole Algorithm” to fill accurately the required holes. Repeating these steps until all holes filled. Fig. 10 shows this process.



Fig. 10. Snapshots for the results after Applying “Hole Filling Algorithm” as well as “Fix Hole Algorithm” for Detecting & Fixing Gaps (Holes) in the Scanned Object.

5- Fig.11 shows the final scan after finishing filling for the object scan.



Fig. 11. Snapshots for the results after fixing all Gaps (Holes) in the Scanned Object.

6- The next process is to apply the true color as well as the texture over the point cloud, using the four scans mentioned before in section (5-2). Figure-12 shows the result.



Fig. 12. Snapshots for the results after Applying Color and Texture over the Scanned Object.

VI. RESULTS

Finally, the final product is to export the object in 3-D point cloud, which in turn can be manipulated in many ways, such as: viewed and evaluated at any viewer software, taking snap shots, or to insert it inside any Augmented Reality Package on Windows or Mobile Android operating systems.

VII. CONCLUSION AND RECOMMENDATION

A proposed scenario: in case of existing geo-referenced point cloud for the entire space of the new Egyptian Museum, every object scanned can be exported as a mesh and re-orient it in the actual place in the Museum.

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