DOCUMENTATION OF ARCHAEOLOGICAL SITES AND MONUMENTS: ANCIENT THEATRES IN JERASH

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ABSTRACT

Modern technology has changed matters in documentation significantly and promises to continue to bring change. This paper attempts to present:-

1-How should we understand documentation of archaeological Sites, historic buildings and monuments according to their particularities, categories, types, components of documentation, taking into account the internationally agreed standards for the documentation of the cultural heritage.

2- The potential of the application of 3D laser Scanner and Photomodeler in documentation of the immovable cultural heritage.

As a case study the ancient theatres of Jerash (the Southern and the Northern) will be presented. While the purpose of using different methods of documentation is to make comparison comparison of the advantages ,disadvantages ,the accuracy of the traditional method – total station –, 3D scanner method, and Photomodeler method.

1. INTRODUCTION

As cultural heritage is a unique expression of human achievement, and since this cultural heritage is continuously at risk, documentation is one of the principal ways available to give meaning, understanding, definition and recognition of the values of the cultural heritage. As such it constitutes an important basis of orientation for subsequent restoration and maintenance measures. Furthermore all interventions acquire the character of evidence themselves and therefore, have to be documented. Article 16 of the Venice Charter emphasizes that in all works of preservation or excavation, there should always be precise documentation in the form of analytical and critical reports, illustrated with drawings and photographs.

Every stage of the work, including technical and formal features identified during the course of the work, should be included. This record should be placed in the archives of a public institution and made available to research workers. It is recommended that the report should be published. Thus documenting the Cultural Heritage not only describes the context in which the materials were found, and their relationship in space and time to geological deposits and large architectural features, but also as monitoring of the remains of past human activities. The documentation process, which may be undertaken as an aid to various CRM activities, such as protection, identification, monitoring, interpretation, registration of stolen cultural objects, can benefit tremendously from various modern techniques that are available to us nowadays.

2. CATEGORIES AND COMPONENTS OF DOCUMENTATION

Regardless of the location of the activity, it type or philosophy of art and historical conservation, the documentation should address three questions: what it is, where it is, and when! There are three Categories and Components of Documentation: **Written:** should comprise an architectural description, the state of preservation , an interpretation of the results of all tests and analyses, a summary of the results of all investigations, and a report on the interventions executed. **Non-photographic (graphic documentation)** Techniques based on conventional surveying to produce plans, elevations, and architectural details. **Photographic** e.g. photography, rectified photography,computer-rectified photography, photogrammetry, and 3D laser scanner. The photographical documentation should provide information on the important condition of a monument, i.e. before, during, and after restoration.

3. INTERNATIONAL CORE DATA INDEX

There are three internationally agreed standards for the documentation of the cultural heritage: a) The Core Data Index to Historic Buildings and Monuments of the Architectural Heritage (1992), b) The Core Data Standard for Archaeological Sites and Monuments (1995), and c) The Object ID (1997) which was developed to provide an international standard for the information needed to identify cultural objects, in response to the threat posed by the illicit trade in the movable heritage.

The evaluation of the documentation process can be carried out by comparison with such standards. Other considerations could be related to the particularity of the monument, the cost, the ability to benefit from modern digital techniques and the success in acting as a historical record of human activities.

4. ANCIENT THEATRES OF JERASH

Few ancient towns are as well preserved and as complete as Jerash, a city complex that once was a thriving commercial zone and part of the Decapolis. Built in the 2nd century BC the city was conquered in 63 BC by the Roman General Pompey. The grand theatres and spacious public squares, plazas and baths, the Roman Cardo running 700 meters north from the Oval Plaza and pass sky-piercing columns flanking from both sides in Jerash make this site truly an archaeological park.

4.1 The Southern Theatre in Jerash

The southern theater *(Exterior Diameter 70.5m)* today is one of the most impressive of Jerash's public building. Begun at the end of the 1st century AD (during the reign of Domitian) and completed in the early 2nd century. On its completion, it became one of the most splendid civic monuments in the developing city and certainly the finest of its type in the whole province. The cavea of the auditorium was divided into two sections, with a wide terrace (diazoma) describing the full half circle between them. The lower half was built into the side of the hill. While the top half was built above it. Although the auditorium has survived remarkably well, the top rows of seats are missing, and one cannot be sure of the exact original number**.**(Figure. 1)

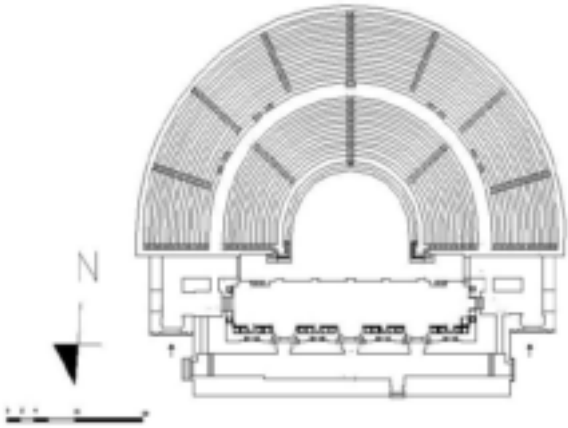


Figure. 1 Plan of the Southern Theatre

The front of the stage was divided into four sections with pedestals between them. Each section was decorated with a central pedimental niche flanked by arched niches .These elaborate architectural compositions are a common feature of Roman theatres. The front of the stage is decorated with pediment and arched niches. The wall rising behind the stage, the Scaenae Frons is pierced by three doors used by the performers to enter and exit the stage from the sides. The Scaenae Frons would have had second storey repeating most of the decorative and architectural elements of the lower level. Much of the outer (north) wall of the theater is a modern reconstruction. The rebuilding, however, of the rear wall behind the scaenae frons must be regretted, for we do not know what this wall was like and such suspect `restorations` run the risk of endangering the validity of the whole structure; for how can one be sure what is genuine and what is not? Happily, the greater part of the theatre is completely genuine. (Browning. Iain/ Jerash and the Decapolis)

4.2 The Northern Theatre

The North Theatre complex is composed of the North Theatre *(Exterior Diameter 43, 47m, orchestra Diameter 14,33m*) itself and a 'plaza' in front of it . A great deal smaller than the South Theatre, its orientation is determined by the northern decumanus upon which it opens and from which it is approached. The cavea shows the usual arrangement of four cunei in the lower half, and eight in the upper half .At the top of the upper section of the cavea there was scarcely room for passageway and colonnade**.**(Figure. 2)

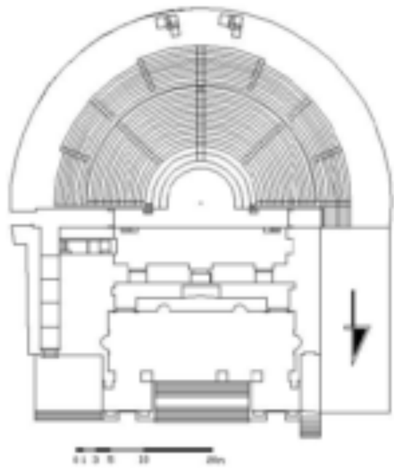


Figure. 2 Plan of the Northern Theatre

The theatre itself probably had two main phases during its lifetime. It was dedicated, and probably completed, in AD 64/65. It was a small, probably, theatre used for poetry readings, meetings or more modest performances than the large dramatic events that would have taken place in the city's larger Southern Theatre. The theatre may also have been the city council's meeting hall. It was- modified several times and probably enlarged in the first quarter of the 3rd century. It finally went out of use as a theatre by the 5th to 6th centuries. On some of the seats of the lower cevea are inscribed in Greek the names of the voting tribes (phylai) that were represented in the bouleutirium, or city council except one tribe named after the Roman Emperor Hadrian, the others are named after Olympian gods. the theatre was also used as a bouleuterion, or city council meeting-hall. The theatre's expansion in the first quarter of the 3rd century AD included the addition of eight rows of seats, doubling the theatre's capacity to around 1600 people.

The three best preserved external vomitoria, at the western end of the upper auditorium, show their original construction of three independent, semicircular arches rising towards the exterior with evidence of large wooden doors that could have been opened or closed to control access to the theatre. The original scaena wall, facing the audience from behind the stage, was dismantled and replaced by a more complex scaena composed of two parallel wal1s. The elaborate scaenae frons was probably two storeys high, and was adorned with colored marble, free-standing Corinthian columns and broken entablatures, behind which were semicircular niches decorated with mosaics.

5. METHODS OF DOCUMENTATION IN JERASH THEATRES

The purpose of using different Methods of documentation of the Southern and Northern Jerash theatres is to make comparison of the advantages ,disadvantages ,the accuracy of the traditional recording method, 3D scanner, and PhotoModeler. Accuracy is the correctness of the measurement, regardless of its precision. Precision refers to the fineness of measured distinctions. Results of the case studies are presented and compared. The aim is to give (mostly nongeodetic) users recommendations, which method is suited best for what kind of application, or even if a combination of 3D scanning and PhotoModeler is advisable. Criteria like quality of the results, amount of cost and time, required equipment and occurring problems are to be considered. To investigate the advantages, disadvantages and the accuracy of these methods, we carried out some case studies for the two theatres. Different typical objects were chosen and characteristically parts of them were recorded by tape, total station, PhotoModeler and 3D scanning. In this research project, we have installed a number of different test targets that allow an investigation in the quality of points recorded by laser scanners and the geometric models derived from the point clouds.

5.1 By using Total Station and AutoCAD Software:

Conceptually, total stations are different from most measuring systems used by archaeologists because they are effective over a great range of scales and have an accuracy that is unusual in our experience. Limits on drawing precision that were once inherent in the use of scaled drawings have been removed by CAD systems. For example, it might be measuring the position of a point 1 km away from the total station and be accurate at least to the centimeter. This is equivalent to the use a tape to measure the distance to an object a meter away with .01 mm accuracy.The total station can be used to measure archaeological structures during an excavation. The precision with which a CAD system can maintain coordinates depends on the internal data structure chosen, but all standard CAD systems maintain coordinates at levels of precision beyond the scholar's capacity to measure. A surveyor collecting data using pre-electronic techniques could have used the tape to take the measurements, together with cross section for elevation information and quantity estimates. Or, the survey could have been completed using such polar techniques as transit or theodolite/EDM surveys. Electronic data collection with total station instruments permits the quick acquisition of a large amount of field data, together with the efficient and error-free transfer of the data to a computer. Once in the computer, the field data can be edited and analyzed for completeness of coverage and accuracy.
For the documentation of the Southern theatre and the Northern theatre of Jerash more than 900 points were taken using the total station (Skoia). Tape measurement was conducted to record some of the dimensions of the theatre (the scene and some architectural details). The goal of these measurements was to collect more field dimensional measurement and other detail measurement for the documentation of the theatres. Full documentation for the Southern theatre of Jerash 2D and 3D was finalized with 2D documentation and reconstruction for the Northern theatre of Jerash.

5.2 By using PhotoModeler:

While photogrammetry and metric surveying techniques can be suitable for archaeological sites and buildings, they present certain disadvantages for smaller and more complex objects. PhotoModeler is a windows software program that helps to extract measurements and 3D models from photographs. By using cameras as an input device, photomodeler is capable to extract accurate measurements and details. It is based on using several photos (Figure 4) from different angles with known focal length, using control points (Figure. 5 **).** PhotoModeler can create 3D models and export the measured data as a dxf file.

ADVANTAGES	DISADVANTAGES
Contains information about surface detail (e.g. weathering patterns).Photographs are easier to interpret and recognize than drawing.	Essential high-skilled photographers.The enlargement of images should do accurately.Photographic format (analogue).

PhotoModeler is one of the methods we used in documenting, measuring, and modeling the scene of the Southern theatre in Jerash. Several selected photos taken from slightly different positions were shot using digital camera. For calibration, some 3D points of the scene were obtained. For this purpose a modern integrated total station model Sokkia to collect more than 50 points to record the 3D points. These points were carefully chosen to be very well distributed on the scene in order to use them as GCPs (Ground Control Points). (Figure. 5) With these data, we produce a 3D model, Orthorectified images (Photogrammetry) and measurements (x, y, z) or lengths for the stage of the Southern theatre of Jerash. For more accuracy we produced a detailed model for the scene features- the left Gate- (Figure. 3) and then combined these detailed models together to produce the scene of the theatre.

Figure 3 3D Model for the left Gate of the scene of Jerash Southern Theatre.

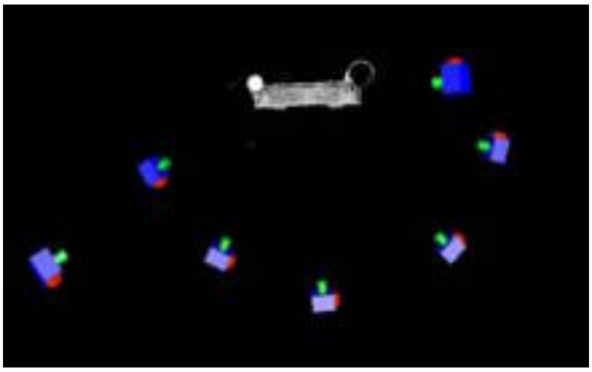


Figure 4. Camera Stations to produce a 3D Model for the the left Gate of the stage of Jerash Southern Theatre

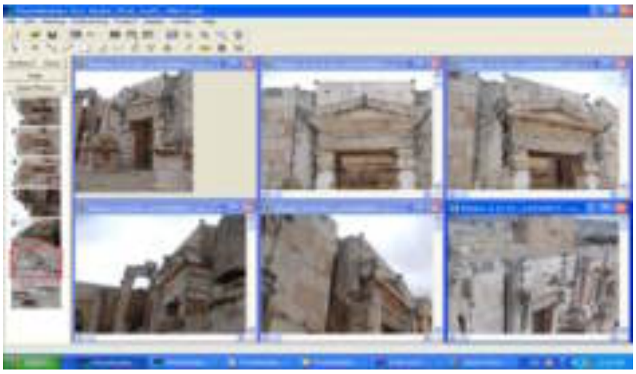


Figure 4. Several photos from different angles with known focal length, using control points for the Scine of the Southern theatre

5.3 By using 3D scanner.

Laser scanning technology with its automated data capture capabilities is bringing new perspectives and can satisfy most requirements of this type of applications. 3D laser scanning represents today the most advanced technology available for measuring and documenting objects. Our scanner can measure on average about 1000 points per second.

Terrestrial laser scanning technology is based on active range sensors measuring directly the distance between the sensor and points over the surveyed object. Objects that can be documented by 3D scanning, range from the sizes of coins or potsherds to whole cultural landscapes. Traditional heritage recording methods like close range photogrammetry are not suitable for all kinds of objects. Particularly when the objects have very irregular surfaces and not a clearly defined structure, scanning will probably yield better results than photogrammetry. In contrast to photogrammetry 3D scanners directly produce a huge number of 3D points. The resulting point cloud can be used to extract CAD elements or - by using point triangulation - to create a 3D surface model. Additionally, images can be mapped onto the model to get a virtual copy of the real object. While both photogrammetric and laser scanning techniques can deliver similar type of products the end users are accustomed to have, other supplementary data such as line drawings, DTM etc.,

A main advantage as compared to close range photogrammetry is the availability of near real time 3D coordinates for irregular surfaces. The striking capability of collecting hundreds or even thousands of points per second is praised by producers and operators. On the other hand, questions concerning the quality and accuracy of the recorded points receive little attention. Specifications stated by the producers are not comparable.

The main difference between scanning and photogrammetry is obvious: While photogrammetric surveying is an indirect data acquisition method (images are needed before measurements can be executed), scanning produces 3D points directly. As geodetic surveying instruments, scanners cannot be used when the object or the observation platform is moving. In these cases, photogrammetric images, which can be acquired with very short exposure times, are the only means of metric documentation. Although surveyors tend to see accuracy as a predominant consideration when comparing measuring equipment, for the practical use there are numerous other characteristics which may be decisive under certain project pre-conditions. Four stages for doing the work: scanning in the field, registration ,segmentation, modeling .

To build up a precise 3D model of the South theatre and the North theatre we used the 3D laser scanner model "GS100 MENSI". The results we've obtained were very precise and the first implementation of the new technology seems to be very useful and promising. The main advantage of scanning is the fast and direct collection of large numbers of surface object points. The measurement process needs no attendance except for the set-up required when establishing a new viewpoint.

The huge number of records formed a nice cloud of points, which very precisely matches the true 3D shape of the interested object (in our case the cavea and the scene of the two theatres). In the office there are two sophisticated softwared, which deal with the collected cloud of points. One of the software can import the clouds and get a nice three model of the object. The other software can also get the 3D model and rectify the model to get the measurements of the object. The final result can be exported to CAD software like Auto Cad or Micro Station. A couple of Million of 3D points were captured from different points of view. In addition to the 3D points, a set of 2D images were also been taken.

In the Southern theater three stations were sat up to capture points of the theater from different angles of view as shown in (Figures 6, 7, 9). In the north theatre we used three stations to cover the whole theater and two stations to capture the surrounding area . All these stations and the cloud of points are shown in (Figures 8, 10).

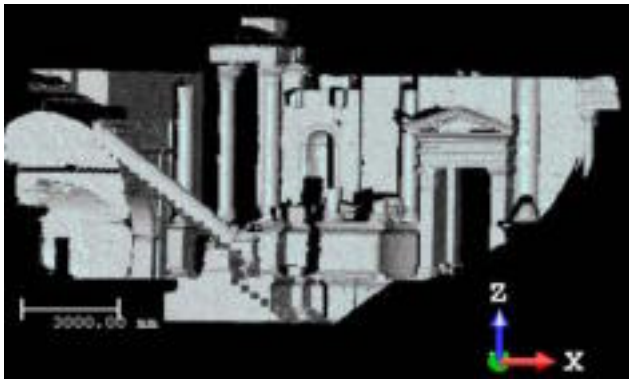


Figure 6. Mesh part of the Scene and the cavea of the Southern Theatre

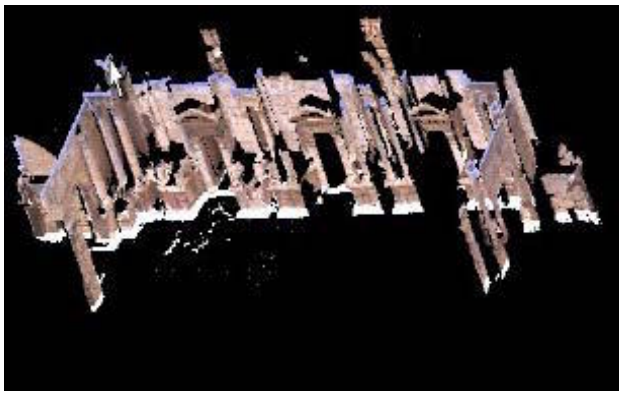


Figure 7. Cloud Points of the Scene of the Southern Theater

ADVANTAGES	DISADVANTAGES
Very precise measurements.	Very expensive.
A solution in situations where 3D measurement by other means may be difficult.	Practical limits on the object size and height.
Quick in data capture.	May have difficulties on some material surfaces.
On-sitescanning is possible.	May have difficulties on some Material surfaces
	Editing the data to produce meaningful results may be difficult.

6. LASER SCANNER DATA ACQUISITION

The laser scanner MENSI GS100 was used in this project and scanning was performed from various positions so that the full coverage of the surface will be achieved with sufficient overlapping **(Fig. 10)**. The specific scanner has a recommended range of 2-100 , with optimal range of m..
The system's horizontal and vertical field of view is 60 degrees. Reflective targets distributed over the site allowed the easy registration of the scans during data processing. Although the laser scanning software provides direct and immediate access to the scan data by visually inspecting the point cloud in situ to identify possible problem areas in the data sets, it proved that some parts of the site were excluded and larger overlap was required for the complete merging of all scans.

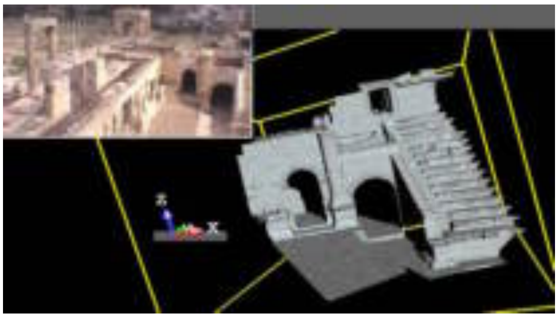


Figure 8. Mesh view of the North theatre

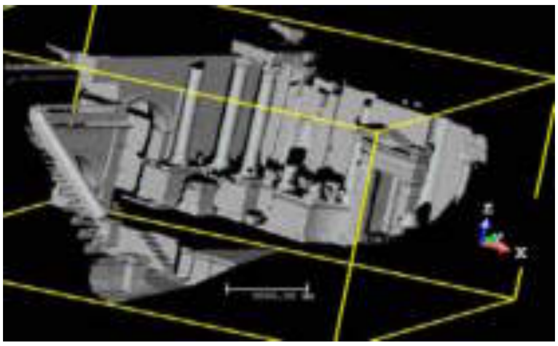


Figure 9. Mesh part of the northern gate of the Southern Theatre

The office work included the use of two software packages:

1) 3Dipsos. Sophisticated software used to reconstruct 3D models from large sets of point cloud data captured by a 3D laser scanner. It is an intermediate data processing application between scanning and the use of environments reconstructed in other applications. The software has the ability to export the final models and solids to Auto Cad using the solid SAD converter.

2) Real Works Survey. Provides the user a set of tools for processing 3D point clouds and 2D images in order to obtain the necessary information. Generally, this processing can be divided into two modes: the Registration mode and the Office Survey mode. During the registration mode we register several scans simultaneously by using data captured during target scanning. Several test fields using white spheres as targets have been installed to get information about the accuracy of distances in scanning direction and across. We also use the Geo Referencing tool to put the scanned data into a known coordinate system. During the office survey mode, we segment the point clouds into logical parts. We also extract measurements or different types of 2D drawings from the point clouds. These extracted results were exported into CAD systems.

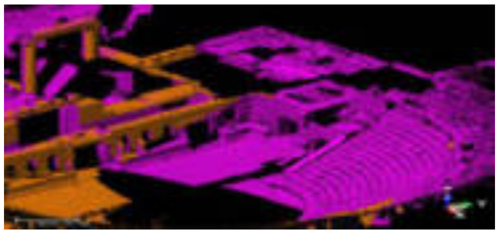
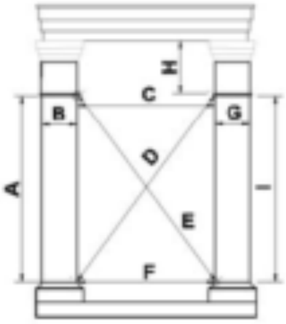


Figure 10. North theatre; Overlapping areas and gaps

Starting with the question of accuracy, it must be understood that total stations have built-in limits on precision that are often ignored and that affect ultimate accuracy. Accuracy refers to the agreement of a value with the "true" value. Whereas the problem was once measuring as precisely as possible or as precisely as a scaled drawing could display, the problem is now to measure and record as precisely as required for the particular project. A comparative evaluation of the techniques in the data capture and modeling of the northern gate of the Southern theatre is shown and measurement results of the Tape measurement, PhotoModeler, 3D Laser Scanner - GS 100 MENSI measurement are presented in **table 1**

Figure 11. Cloud Points of the Cevea of the southern Theatre



N	Tape Measurement (CM)	PhotoModeler Measurement (CM)	3D Laser Scanner - GS 100 MENSI
A	253	248.8	254.153
B	50	50.2	49.1
C	187	187.4	186.445
D	314.45	311.9	319.096
E	315	310.2	314.948
F	186.7	186.7	188.310
G	49.5	50.2	48.80
H	71	71	68.4690
I	253	249	251.149

Table 1

7. CONCLUDING REMARKS

The documentation of the Jerash theatre was implemented by a combination of photogrammetry and 3D laser scanning. Generally:-

- Hand survey is labor intensive specially in the field.
- Computer rectified photography is the simplest method of producing drawings. Metric cameras are no longer needed and can be substituted for with simple digital cameras.
- The advantage of using photogrammetry is its speed and accuracy, especially over large and complex structures.
- Cost will inevitably be one of the deciding factors in choosing between different recording methods, but should not be used to decide the level of survey.

The effort needed to get accurate and detailed DEM models by means of photogrammetric procedures only, is considerably high. There are limits on precision based upon a different group of contributing factors, lens distortion, precision of lens focal length measurements, size of photos used.

PhotoModeler is an elegant measurement method used in documentation of cultural heritage applications. The shortfalls of this method, mainly associated with limited geometry of areas in the shadow of the object, are more prominent when the object is a large complex form. However its use does not involve large costs or sophisticated equipment, as only a calibrated digital camera is needed. The recent emergence of terrestrial laser scanning has shown that it has the potential to be of major value to the cultural heritage recording professionals. While data collection in this project using the PhotoModeler and Laser scanning methods indicated a small gain in time over laser scanning, the main advantage is the fully automated data capturing process using terrestrial laser scanning. Generally, laser scanning requires viewing the surveyed object from several viewpoints to resolve shadows and occlusions.

To achieve the best accuracy in PhotoModeler:

1. Ensure that a well-calibrated camera is used for the project,
2. Use photos with good resolution.
3. Ensure that the angle between the camera stations is as close to 90 degrees as possible,
4. Ensure that all points appear on three or more photographs,
5. Ensure all point and line markings on the images are precise, and do not guess at a point location if it cannot be seen, is not distinct, is fuzzy or is hidden by some other object.

Nevertheless, the precision supplied by total stations or photogrammetry software and recorded in CAD models must not exceed the limits on accuracy of the total system and must be appropriate for the job at hand. As already stated, every project has its own particularity. Those needs should be carefully determined, explicitly stated, and properly met by the survey methods and procedures. Laser scanning provides dense 3D information that can be implemented for the DEM and also for the determination of the ground coordinates of pre-signalized control points. The large sets of data obtained are an impediment to virtual computer visualization. Often it is very difficult to deal with the data without large RAM memory of the order of two GB.

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