Towards Creating a Dialogue between the Specialized Technician and non Technician Users of the 3D Laser Scanner

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ABSTRACT

Several attempts and case studies had been conducted to document the cultural heritage using the 3D Laser scanner in the last few years. Now, it is possible to furnish a virtual model of an object from the pointcloud and to complete the direct measurements, just like if the user were physically present on the site. While the main users of this method are technical people (not archaeologist), the results of these studies could not be easily understood and clearly appreciated from a majority of the people involved in the process of documentation for the archaeological sites and monuments. By reviewing the latest articles and case studies of 3D laser scanner in heritage documentation, we can establish now, some general rules and recommendations, mainly for the non technical users involved in the process of this new documentation method and according to their actual needs. This paper attempts to present and evaluate the recently 3D laser scanner achievements and results in heritage documentation to create a dialogue between the specialized technician and non technician users, in order to decrease the gap and to build a bridge between them, taking into consideration the following factors: 1-Kind and type of the structure.2- Material and texture.3-Scale of the structure 4- Acquisition time in the field and the number of the required scan positions. 5- Data post processing time in the lab. 6- Accuracy and precision. 7- Benefit ratio and cost.

1. INTRODUCTION

Today, the laser scanners are widely used in the field of architectural, archaeological and environmental surveying because of their practicality and flexibility. They represent today the most advanced technology available for measuring and documenting objects. Terrestrial laser scanning technology is based on active range sensors measuring directly the distance between the sensor and points over the surveyed object [10]. With its automated data capture capabilities, it is bringing new perspectives and can satisfy most requirements of those types of applications.

Two different principles for distance measurement are in use: Lasers using the “time-of-flight” principle and instruments using CCD cameras, where distance measurement is based on the principle of “triangulation” [11]. The triangulation method is most useful for smaller objects, while time-of-flight method is most useful for large objects. Objects recorded include statues, a sculptural arrangement, an unearthed wood structures and architectural facades and complexes. However, we can assume that laser scanning is a valuable new tool for cultural heritage documentation and one which will complement, and, in certain applications, replace currently some of the existing methods

2. THE NON TECHNICIAN USERS AND POTENTIAL OF THE APPLICATION OF PHOTOGRAPHIC DIGITAL METHODS IN DOCUMENTATION OF THE CULTURAL HERITAGE

It is a fact that, photographic and non-photographic (graphic) documentation tools are merging in one process, in which the digital photographic technology is the main base. However, by the 3D digital technology, actually, there is an increasing gap between the specialized technician and non technician users, involved in the cultural heritage documentation. Although the 3D model provides a correct and complete documentation of the object, 3D supports are still not popular among users in cultural heritage; it is not a so easy tool to deal with by unskilled users.

However, the aspects, which most involve the user, are both the interface and easy access to the documented data. A survey based on an orthophoto allows users to put together different levels of abstraction (such as in the traditional drawings) with the realism of a photographic image. Orthophoto as a product connects the survey data and the representation; meanwhile it allows an easier communication between the specialized technician and non technician users, compared to other survey products.

On the other hand, an orthophoto as an interpreted survey product allows specialists to point out and manage information about many elements of the documented object on different layers, which is a very important issue in the cultural heritage: e.g. architectural elements, shape relationships, construction techniques, material texture, historical phases, color values, decorative elements, decay conditions, etc. These elements are legible on the orthophoto with a metric reliability and a verifiable precision [4, 8]. Furthermore, the solid image lets the user access and manage 3D data simply by viewing a 2D monoscopic image; it adds correct 3D metric information to simple photos, so that information is much easier to access by users [4, 12].

Actually, Computer-aided design (CAD) is the optimum assembly platform for 3D data set. The use of CAD software for documentation removes any impact of drawing scale on the process of measuring and recording, and brings a different but related concern about precision to the fore. Therefore, limits on drawing precision, that were once inherent in the use of scaled drawings, have been removed by CAD systems [14.15], and can provide such precise dimensions to any user.

In the last few years**,** several 3D objects were documented, such as statues, in order to realise a true reference copy of sculptures heavily exposed to environmental degradation. On this case a relevant difference arises during the acquisition process *in situ* compared to a laboratory process. [9, 16, 17] However, Digital photogrammetry methodologies and LIDAR (LIght Detection And Ranging) techniques, in recent years have undergone an important technological progress; furthermore their integrated use allows complete and accurate survey products to be easily created [3, 17].

Now architectural scale surveys on historical buildings and, archaeological sites using digital photogrammetry and LIDAR methodologies have several peculiarities, such as the instruments used (degree of reliability and precision), representation methods (flexibility degree and amount of information), research approaches (degree of explorability, interdisciplinary nature and transformation) and means of communication (degree of compatibility with other technologies and ability to diffuse) [8, 12].

The rapid advances being made at the moment in terms of delivering 3D interactivity over the Internet with respect to the Virtual Reality Modelling Language (VRML) will make fast interaction with virtual historic monuments and precincts more than feasible. A combination of different methods until now often leads to the best results and less time. Therefore, users dealing with documentation accompanying any CAD model should not only discuss issues of data precision (and data density); so that users will have the necessary information about the precision with which dimensions were made, but simultaneously they should also discuss the comparable issues of achieving visualization in combination with image determination, possibility of automated image rectification.

Finally, in order to obtain a correct representation of large complex historical structures, it is necessary to plan specific survey and representation techniques. Planning and preparation of the fieldwork can solve a lot of problems. Actually, partitioning processes and integration of different measurement and modeling techniques appear to be useful in cultural heritage documentation and representation [2].

3. THE POTENTIAL OF 3D LASER SCANNER AND THE NON TECHNICIAN USERS

To understand and evaluate 3D leaser scanner documentation of the cultural heritage, there are certain needs which should be carefully determined, explicitly stated, and properly met by the documentation methods and procedures. These needs depend on: 1-Particularity of the documented object, structure, monument and site. 2- Cost and Time. 3- Monitoring of the remains of past human activities.

Several attempts and case studies had been conducted to document the cultural heritage using the 3D Laser scanner in the last few years. Now, from the pointcloud it is possible to furnish a virtual model of an object to complete the direct measurements, just like if the user were physically present on the site.

Examples of applications using laser scanning techniques with encouraging results are found in Adolfsson (1997) [1], Beraldin et al. (2000) [9], Levoy et al. (2000) [18], Rocchini et al. (2001) [20], Henz (2002) [16], Tsakiri et al.(2003) [21], Boehler et al. (2003) [11], Bornaz et al. (2004) [13], Agosto et al. 2005) [3,4, 5], Artesea et al (2005)[8].

As the main workers of this method are exceptionally technical people (not archaeologist and architects), the outcome of these studies could not be easily understood and obviously appreciated from a majority of the people involved in the process of documentation for the archaeological sites and monuments. However, the familiarity of the user or expert with one of the methods is often the deciding factor in which a method is used and not the optimal suitability in practice of the method to the intended purpose [14].

On the other hand, the different technical areas that the documentation of cultural heritage deals with, use different classifications for the description of the degree of detail, furthermore these are not uncontroversial within the technical world itself. These classifications are connected with a scale specification [15]. Whereas the problem was once measuring as precisely as possible or as precisely as a scaled drawing could display, the issue now is to measure and record as precisely as required for the particular project.

In the face of reviewing the latest articles and case studies of the 3D laser scanner in heritage documentation, we should now start to establish, some general guidelines and recommendations, mainly for the untrained users involved in the process of this new documentation method according to their actual needs. This will be helpful in order to decrease the gap and to build a bridge between the specialized technician and non technician users of the 3D laser scanner in heritage documentation.

New technologies are difficult to be observed by the multidisciplinary community involved in the cultural heritage. Total station applications in heritage documentation needed a good 25 years to become a popular tool. 3D scanning is in its first stage of applications. Accessing and popularity this medium needs a strategy and guidelines for the assistance for the non comprehensive technical users to be familiar with the technical qualities of this new digital tool.

It is a major issue that the specialized technician didn't present the above to non technician users, because most of them are not archaeologists, historian architects, or conservators. To Bridge the gap between them; this must start by the modifications required in the nature of the courses in postgraduate phases. This may be clear, at least, in the Arabic region case, where most of the nature of the courses did not consider or understand the value of this must interaction multidisciplinary approach.

However, these guidelines should take into consideration the following factors: kind and type of the structure, material and texture, scale of the structure, acquisition time in the field and the number of the required scan positions, data post processing time in the lab, accuracy and precision and benefit ratio and cost. These factors should be clarified and identified to the non technician users dealing with the heritage documentation. Following is a general overview of those factors.

4. FACTORS TO BE CLARIFIED FOR THE NON TECHNICAL USERS

4.1 Kind and type of the historic structure

Due to the high point density 3D laser scanner it is suitable for the determination of equalizing free-forms, ideal for large and high details building, providing solution in situation where 3D-measurement by other means maybe difficult. Though, 3D scanners are especially useful when dealing with objects that are asymmetric and complex in terms of the number of curves and ridges such as parts of a skeleton and caves**.**

On the other hand, for the documentation of object like statues, there is generally a difficulty to place volumetric or reflective targets [16, 19]. In this case, the use of the ICP (Iterative Closest Point) algorithm can be considered the most effective. Furthermore, some control points (well visible points on the statue) should be used to verify the registration of the 3D images, while external control point scape should be used to obtain the global alignment [8].

However, the use of scanners for recording the remains of cultural heritage has a serious theoretical problem: the points actually recorded are determined by the placement and discrimination of the scanning grid. Until and unless the operators of these scanners can choose the particular point's surveyed, 3D scanners are not appropriate technology for documenting all types of the architectural monuments; due to different grid widths and spot sizes, not all 3D scanners have the same abilities to resolve small object details. They are also known to produce errors at edges.

Although the laser scanning software provides a direct and immediate access to the scanned data, by visually inspecting the point cloud *in situ* to identify possible problem areas in the data sets, it was proved that some parts of the scanned object or site were occluded and thus a larger overlap is required for the complete merging of all scans [1, 17]. Actually, laser scanning requires viewing the surveyed site or object from several viewpoints to resolve shadows and occlusions. Therefore, we need to establish how reliable are the instrument, in relation to the type of the object**.**

4. 2 Material and texture

As laser scanning is an optical method, it is of interest to investigate the influence that illumination and material type have on the reflection of the laser spot and the resulting quality of the measured points. In addition to the surrounding light intensity, the color and surface of scanned objects are important. There are some surfaces, which could not scan particularly well (any transparent material such as glass, mirrors, water, and crystal). However, in most cases it is possible to modify the surface to make it suitable for scanning.

The best reflection of the laser light is achieved from smooth red surfaces, like the red spheres delivered with the scanner. When the object is rough and dark, much of the laser light is absorbed and missing points can be observed. Meanwhile, scanner laser metric data are actually particularly effective in surveying and modelling sculpturistique and smooth surfaces, they sometimes fail in capturing and detecting sharp edges and lines of intersection, which are essential for a correct representation of architecture [2].

Furthermore the laser beam hitting the surface that is normally not smooth is reflected in various ways according to the local superficial roughness. Actually, the type of the material hit by the pulse determines the intensity of the returning signal. These sometimes produce a degradation of the quality of the range data and it may even happen that no signal at all will return [2, 6, 7]. For example, red bricks were found to respond poorly to some scanners while the mortar provided a good response. Meanwhile, as reported in literature, marble depart from this hypothesis, and exhibits two important optical properties in this context: translucency, and non homogeneity at the scale of the measurement process. This structure generates two key effects on the geometric measurement: a bias in the distance measurement, as well as an increase of the noise level. Thus, the typical problems of laser scanner acquisitions, due to highly reflecting surfaces have yet to be solved.

4.3 Scale of the structure

The objects that can be documented range from the sizes of coins or potsherds to whole cultural landscapes. When scanning artificial objects like sculptures etc., a strong smoothing of the point clouds is necessary to reduce their thickness and to create a flatter surface for triangulation. Of course, this also results in a loss of detail and therefore should be used with extreme caution [11]. However, the end users are accustomed to have, such as line drawings, DTM etc.; the interest mainly lies in the supplementary role the 3D laser scanner type of data can have in 3D model creation [1, 10, 19].

In contrast to photogrammetry, 3D scanners directly produce a huge number of 3D points, where the resulting point cloud can be used to extract CAD elements or - by using point triangulation - to create a 3D surface model [10, 11, 17, 19]. Additionally, images can be mapped onto the model to get a virtual copy of the real object. Furthermore, 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.

Since obstruction can lead to gaps in survey requiring completion, there are practical limits on the objects size and height and may have difficulties on some material surface. By scanning surfaces at an angle of approximately 45°, better-looking results are achieved; the thickness of the cloud of points is smaller because the direction of the main error component is no longer perpendicular to the surface. However, from the 3D model, it is possible to realize a section with a horizontal and vertical plane in the different zones of interest which is essential for huge scale and complex structure. To do this it is necessary to reduce the amount of processing data between 15% - 20% before the data post processing.

4.4 Acquisition time in the field and the number of the required scan positions

For most of the projects it is necessary to scan from several viewpoints, since scanning should be performed from various positions so that the full coverage of the surface will be achieved with sufficient overlapping. Actually, laser scanning machines can be considered as a high automation reflectorless total station; by means of a laser based measurement of distance and accurate angular movement, a target object is sampled in a regular mesh of 3D points. The operator only selects the portion of the object he wishes to acquire and the density of the points he desires in the scan. Once these initial values have been chosen, the acquisition is completely automatic. However, 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.

The spheres are useful as connecting points at distances up to 10 meters. Placing them further away leads to problems due to decreasing point accuracy. Processing procedures should include recognition and elimination of wrong or inaccurate points. Since most objects have to be recorded from several viewpoints, methods to combine the separate point clouds have to be incorporated. In general the LIDAR technique allows "*in situ*" the surveying time to be reduced but it slightly increases the processing time [11].

4.5 Data post processing time in the lab

Scanning results is a cloud of isolated 3D points. The laser scanner data treatment consists of the pre-treatment (or preliminary treatment) of the laser data and the solid modelling of the point cloud. Point cloud and mesh data can be loaded into AutoCAD. However, AutoCAD is not primarily designed to handle these massive datasets and performance may be sluggish. The data (point clouds and images) are stored in a single reference frame [8]. Furthermore, as the laser scanners randomly acquire a dense set of points, the result of the laser survey is a very dense point cloud acquired in a completely arbitrary way, except for the parameters set by the operator.

However, after scanning, the edges or projecting parts points have to be removed manually from the cloud of points through a time-consuming process, but as every 3D point in 3Dipsos looks the same, it is difficult to identify the incorrectly placed ones and to be sure that no correct points are deleted [11]. From the point cloud it is possible to furnish a virtual model of an object to complete the direct measurements, just like if the user were physically present on the site [5].

Therefore, particular attention must be paid during the analysis, the processing and the modelling phases of the laser scanner data. This means that it is necessary to manage this data in a critical way [3, 4]. On the other hand, the point clouds are an immediately rich data set, already a starting point for many activities. Actually, it covers most of needs for the non technician users involved in the cultural heritage documentation as it can be directly used for 3D visualization, point to point measurements and stored for subsequent use.

Therefore, users should be well aware that, in addition to appropriate software, time and patience are needed to arrive at a final result in the form of a CAD drawing or a surface representation with a triangulated mesh [11]. The problems related to the registration of 3D images and to the global alignment, can be solved by different ways; some methods use tie points (generally 4 or more) in two 3D images which are to be merged. One of the most popular methods is the ICP algorithm. Other procedures use retro-reflecting or volumetric (conical, cylindrical, spherical) targets. In this case, it is possible to calculate the position and the sensor orientation data during acquisition of the 3D images [8, 12]. In the meantime, the LIDAR technique can provide high productivity in creating a Dense Digital Surface Model (DDSM).

Actually, the fast and economic way of creating a DDSM is one of the most interesting applications of such an instrument; if other techniques (e.g. total stations, photogrammetry) where to be used it would be an incredibly time-consuming process. Thanks to the digital camera mounted on scanner machines, it is possible to immediately assign RGB information to each point [3.8].Therefore, by using an accurate planning and some defined procedures; it is possible to reduce the time necessary for the batch processing [3].

To create a detailed 3D model within a justifiable amount of cost and time expenditure for a bronze statue 80 cm high needed 1 working day for scanning using 11 view points and 780,000 recording points. The whole process of evaluation to create a detailed 3D model (including application of textures) took about 10 days for post processing. However 355,000 points were used for the mesh. An experienced user may need only half as much time. Geometrical mesh construction took five days and texture application took another five days. An experienced user may need only half as much time [11].

A copper statue, life-size (178 cm), needed 29 view points with 1.8 million recording points. The resulting model consists of about 1.000.000 points. A stone Statue (Marc Anton) 3m height needed 2.5 hours for scanning with 10 view points and 7.4 million recording points, the point cloud was reduced to about 1.4 million points while at every scanner position two scans were acquired. The number of points was reduced from about 7.4 million to about 4.0 million points. A wooden Roman Boat 15 m length 3 m width needed 8 nights, with 30 view points and 9 million recording points and needed 45 days for post processing. However, the final point cloud amounted to 1.6 million points. A sandstone sculptures 4 by 10 m, needed 2 hours for scanning with 1 view point and 3 million recording points. However, two more viewpoints were used to create a denser point grid and to reduce the shadowed areas.

In architectural examples, the main support wall of the acropolis in Athens needed 20 hours for scanning and one day for post processing, which can be considered ideal. While the theatre "Linz" in Austria needed 20 hours for scanning with 26 view points and needed 2 days for post processing. However, in archaeology the example of the "Inner city", 7 by 8 m, needed 6 hours for scanning while 7 days were needed for post processing.

Therefore, from these examples it is clear that, the amount of energy and time to create an accurate and faultless model is many times larger than scanning time (roughly by factor 5 to 10 or even more). Both, software and hardware have to be improved, to relieve the post processing and to make laser scanning an economical option as compared to existing documentation methods.

4.6 Accuracy and precision:

Tests show that the point accuracy depends slightly on the reflectivity of the scanned object, especially at short distances. The accuracy is between some millimeters and two or three centimeters, depending to some extent on the distance between the object and the scanner. Meanwhile, the accuracy of the laser scanner acquisitions allows detecting some manufacturing characteristics of artistic works, useful for recognizing the paternity of these works [8]. However, with triangulation scanners 3D point standard deviations is less than one millimeter at very close range (less than 2 meters).

The accuracy depends on both the length of the scanner base and the object distance. With a fixed base length, the standard deviation of the distance measurement will increase in proportion to the square of the distance. It can be predicted that point accuracy is constituted only by the accuracy of the distance from the laser mirror and that this accuracy decreases with the square of this distance [11].While there is no improvement in the accuracy using laser scanned data, mainly because of the large number of overlapping photos which should be taken, there is a significant gain in labor associated tasks. The comparison between orthophoto derived from:-

(a) Typical photogrammetric process (b) use of DEM derived from laser scanning and implemented in the orthophoto, and (c) use of DEM derived from laser scanning and photogrammetrically derived breaklines, revealed that very small systematic deviations existed and the achieved accuracy satisfies the specifications at scale of 1:50 [14]. However, specifications stated by the producers are not comparable. 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. This also applies to the suitability of 3D scanning equipment.

4.7 Benefit ratio and cost

So far we have been able to scan a number of different objects and sites. The documentation process with 3D Laser scanner committed to cultural heritage actually reflects a reasonable degree of complexity. The increasing of computers performances allows the management of very large point clouds, and discovers interesting perspectives for the utilization in the cultural heritage, where 3D models can be obtained using the high density surveying of real objects.

Though, 3D Laser scanner should be oriented and considered as one of the most effective instrument in monitoring (3D monitoring) of the remains of past human activities of the cultural heritage, hence, it is a very quick in data capture, with flexibility in 3D digital format data and very precise and accurate measurement instrument. Actually, good surface-determination obtained even with low single-point accuracy because a large number of points exist.

Since close range photogrammetry is 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 due to availability of a near real time 3D coordinates for irregular surfaces [10, 11, 16, 17].

On the other hand, we can present the scanned monument and propose an interpretation established in advance or try to offer to visitors all the necessary elements in order to understand and evaluate autonomously, especially the navigable 3D model which can be easily generated. This kind of model is an extremely useful tool to make a representation of a complex object. This kind of presentation has a remarkable impact on the public and it is suitable, for example, to show the 3D products in a show room. However, an untrained user could find this representation not so easy to deal with [3, 4].

Nowadays 3D scanner is very expensive, need high skilled operations and processing can be time consuming, while editing the data to produce meaningful results maybe difficult. The main idea for future developments is, taking advantage from structured contents, is to enhance the use of profiles tailoring both content and interface accordingly with the needs of users. Major part of such a task should be carried out in background using smart agents and user tracking methods. Final aim is to modify the 3D Laser scanner system output in order to satisfy user requirements, providing the right content within the right format and interface.

5. CONCLUDING REMARKS

In comparison with other issues of the cultural heritage (conservation, restoration, and protection), the impact of modern photographic technology, actually, the last 30 years is obvious and clear in the quick evolution of heritage documentation. Now, we are in a position to consider if such investments are effectively useful and really increase and diffuse knowledge in cultural heritage to satisfy users' requirements. However, new technologies are difficult to be observed by the multidisciplinary community involved in the cultural heritage.

Thus, a dialogue must now be created between the specialized technician and non technician users, involved in the process of documentation of the cultural heritage; they must now not only aim for the precision required, but also for 3D accuracy standards which can now actually be achieved by the modern technology of 3D scanning. They should not only discuss issues of data precision required and 3D accuracy standards, but they simultaneously should also discuss the comparable issues of achieving visualization production system according to different variables, which can now actually be achieved by the modern digital technology of the photographic method of 3D laser scanning.

Total station applications in heritage documentation needed a good 25 years to become a popular tool. 3D scanning is in its first stage of applications. Accessing and popularity this medium needs a strategy and guidelines for the assistance for non comprehensive technical users to be familiar with the technical qualities of this new digital tool, in which and a relevant difference arises in the acquisition process *in situ,* compared to a laboratory process. This concept is completely different from the traditional graphic documentation process, where the *insitu* need more time than the laboratory process and approach.

Though, a dialogue between them now is a must. However, documentation is not only needed now for proper conservation, but foremost to raise public awareness and to monitor the remains of past human activities. It must be realized that documenting the cultural heritage can be achieved easily by the digital technology of photographic methods especially using the 3D Laser scanner technology.

This should be the new target for the technical and geodetic people involved in the digital technology of photographic documentation of cultural heritage. This facilitates the generation of historical and archaeological experiences using the techniques of computer animation, while reducing the need to reconstruct the historic sites. Therefore, as 3D scanner as a tool is "neutral", and as user makes the difference, by bridging gaps between the specialized technician and non technician users, the digital technology of 3D scanner can play a positive role in the field of culture heritage.

On the other hand, the point clouds are an immediately rich data set, already a starting point for many activities. Actually, it covers most of the needs for the non technician users involved in the cultural heritage documentation as it can be directly used for 3D visualization, point to point measurements and stored for subsequent use. However, in the case of huge scale and complex structures, in order to obtain sections with a horizontal and vertical plane in the different zones of interest, it is necessary to reduce the amount of processing data between 15% - 20% before the post processing.

While in the application fields where high accuracy is important, the users that belong to the strict portrayal-school should now accept that they have to deal in the field, with other new documentation and interpretation methods, other than the hand measuring and tachometry. However, hand survey has the ability for *in situ* observation and maybe cheaper than the photographic process for small areas.

Actually, among the several techniques used for the documentation of solid objects, 3D laser scanning has shown that it has the potential to be of major value to the cultural heritage recording professionals and can play a significant role in the subject of monitoring. Meanwhile, the use of LIDAR allows 3D accurate metrical models for the presentation and interpretation of the cultural heritage, of a large and complex architectonical objects and structures.

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