European Scientific Journal August 2013 edition vol.9, No.24 ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431

THE NEED FOR 3D LASER SCANNING DOCUMENTATION FOR SELECT NIGERIA CULTURAL HERITAGE SITES

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Abstract

Heritage sites documentation with 3D laser scanning has proven to be great way of preserving information and narratives about these sites in a very detailed and complete style to facilitate reconstruction if, peradventure, their significant part is lost to natural or man-made disaster. This spatial information forms not only an accurate record of rapidly deteriorating sites, which should be saved for posterity, but also provides a comprehensive base dataset by which heritage site managers, archaeologists and conservators can monitor and perform necessary restoration work to ensure physical integrity of cultural sites. In the past, traditional methods of documentation such as direct hand measurement and drawing at the point of capture have been used for documentation in West Africa heritage sites, for example Nigeria. These methods are not only time consuming but prone to several and large scale error especially when it requires high density point capture. This paper suggests way of documentation that will provide accurate data in shorter duration of time, especially for heritage structures with irregular and unmarked geometrical details, by using 3D laser scanning technology. This technology can produce detailed 3D model, two-dimensional (2D) drawing, and a guide to preservation and virtual reconstruction of heritage sites.

Keywords: 3D laser Scanning, Geometric Documentation, Cultural Heritage

Introduction

Today, the world is losing its architectural and archaeological cultural heritage faster than it can be documented. Human-caused disasters, such as war and uncontrolled development, are the major factors. Also, natural disasters, neglect and poor conservation are also among the reasons that cultural heritage is vanishing. In Nigeria for example, climate change and social unrest have been rapidly increasing, especially in its Northern region. Over the centuries, this type of phenomenon has been known to influence the existence of civilizations even in its slower, more 'natural' cycle. (*Jayaram*, 2013). In 2012, there was a drastic change with incessant variations in rainfall, flash-floods, landslide, armed conflicts and disasters that are not only wreaking havoc across towns and cities, but posing a threat to various forms of existence in this geographical location (Onwubiko, 2012; Onyekwere, 2012). The built environment, especially buildings and cities of historical importance, are particularly vulnerable to the impacts of these challenges.

Documentation forms the basis for any conservation project (*Jayaram*, 2013). Its role in the management of the Nigeria cultural heritage site has long been recognized even as it is indispensable for purposes of identification, protection, interpretation and physical preservation. In Nigeria, the scheduled heritage sites are the identified, documented and declared national monuments by the National Commission for Museums and Monuments (NCMM) under decree No. 77 of 1979 of the country's constitution. Nonetheless, some of these sites are facing great threat due to encroachment as a result of uncontrolled human activities which have deeply defaced them and in future may probably render them extinct due to lack of 3D geometrical documentation. The sheer number of cultural sites that are without sufficient documentation is on the rise, further confirming the estimation that only a third of the eight hundred sites on the World Heritage List are adequately documented (LeBlanc *et al.*, 2005) in terms of geometric documentation.

Geometric documentation of a monument is an adequate way to document cultural heritage and can be digitally achieved via 3D laser scanning technology. According to UNESCO (1972), this method of documentation may be defined as "*the act of acquiring, processing, presenting and recording the necessary data for the determination of the position and the actual existing form, shape and size of a monument in the 3D space at a particular given moment in time*". This type of documentation records the present state of monuments, as this has been shaped in the course of time and a necessary background for the study of their past, as well as the plans for their future. It involves a series of measurements and in general metric data acquisition for the determination of the shape, size and position of object in 3D space. This documentation consists of suitable projection on predefined horizontal and vertical planes of a number of points (connected with lines) which best describe the shape, the size and the position of monuments in the 3D space. (Ioannides *et al*., 2005).

With 3D laser scanning, the surface geometry of objects or building is detected by laser beams digitally. This produces a discrete set of three-dimensional sample points (point cloud), where the coordinates of the horizontal and vertical angles and the distance to the device location (polar coordinates) are determined (Gadou *et al*., 2011). This technology has produced firstly a large number of projects, mainly led by research groups, which have realized very good quality and complete digital models (Levoy *et al*. 2000; Beraldin *et al*. 2002; Stumpfel *et al*. 2003; Guidi *et al*. 2004; Gruen *et al*. 2004; Ikeuchi *et al*. 2007; El-Hakim *et al*. 2008; Guidi *et al*. 2009; Remondino *et al*. 2009). Secondly, it facilitates the creation of guidelines describing standards for correct and complete documentations thereby allowing the generation of very realistic 3D results (in terms of geometry and texture) used for many scopes like archaeological documentation, digital conservation, restoration purposes, virtual reality and computer graphics applications, 3D repositories and catalogs, web geographic systems, visualization purposes and many others **(**Remondino *et al*., 2010).

3D documentation has been passed as an obligation for protection, conservation and restoration of monuments by international bodies and agencies in the past. For instance, the Athens Convention (1931), the Hague Agreement (1954), the Chart of Venice (1964) and the Granada Agreement (1985) are only but a few of these resolutions in which the need for geometric documentation of monuments was also stressed, as part of their protection, study and conservation. Furthermore, in the United Kingdom there have been several efforts in creating standards for surveying in the area of Cultural Heritage in the past few years. 3D Laser scanning was discussed as well as its adoption worldwide (Ioannides *et al*., 2006). In line with different expert's opinions on this aspect across the globe, it would be interesting and cost-effective to adopt the use of 3D documentation technology to preserve the many historic sites in West Africa, particularly in Nigeria before they fall prey to the pressure of development, social unrest, climate change and other unforeseen factors. Moreover, people are often attracted by impressive evidence of the past and rarely realize small treasures like the art and history that surrounds these heritage sites. This marginalized but important knowledge can be "awakened" by 3D reconstructions that have a high metric accuracy as well and are obtained on the basis of the point cloud detected by laser scanners. Thus, by making the cultural heritage virtually accessible to everyone, the laser scanner becomes an essential tool for dissemination of artistic heritage (Guarnieri *at al*., 2010; Meyer *at al*., 2002).

Some Principles and Features of Laser Scanning Technology

A laser scanner collects a large range of data representing three-dimensional coordinates, called point cloud data as shown in figure 1. The point cloud is a collection of (X, Y, Z) coordinates in a common coordinate system that portrays to the viewer an understanding of the spatial distribution of an object. For most laser scanning instruments, the point cloud can be regarded as the raw product of a survey. They may also include additional information, such as return intensity or even color values. Generally, a point cloud contains a relatively large number of coordinates in comparison with the volume the cloud occupies, rather than a few widely distributed points. The point cloud density depends on the relative distance between the coordinates. It can represent a single or a number of small or large objects to form a part or

Figure 1: Point Cloud (Artescan).

whole of a building or site. These large amounts of data, which represents three dimensional coordinates of an object or site, must be processed in order to abstract geometry, shape, measurements and texture. Proprietary software such as Polyworks, Leica Cloud works for AutoCad and RiScanpro is required to manipulate massive amounts of the 3D data as shown in the workflow (figure 2). The point cloud can be used as a visualization tool before processing the entire data captured. The scan can be colored from the images taken from the same position as the laser scanner by Digital photo image modeling, used alongside the scanner. Though the scanner can be used independently to collect data, but where it is not appropriate, the laser scanner is combined with a digital camera, which captures corresponding images to the scan as shown figure 1 above. Appropriate software is used to combine the image and scanned data. Boehler et al.,(1999).

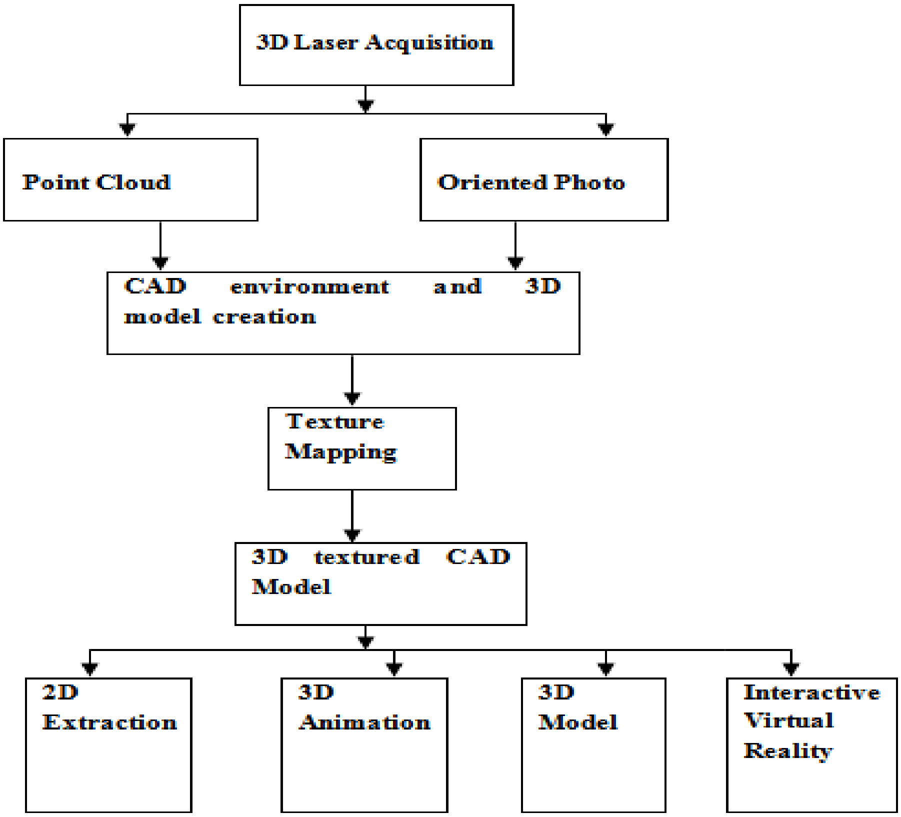

Figure 2: 3D Modelling Workflow

The Importance of 3D Laser Scanning For Cultural Heritage Documentation

Terrestrial 3D laser scanner devices represent the most widely investigated instruments among architectural and archaeological surveying applications. This is because these devices in their data acquisition process allows collection of very huge amount of data with accuracy in the range of centimeters or even millimeters, which produces dense, accurate and detailed models (Doneus *et al*., 2009). Over the years, 3D laser scanning has become the standard procedure for documentation of cultural heritage due to its ability to rapidly create a highly detailed (dense) accurate representation of complex structures. Consequently, it is increasingly being used in the field of cultural heritage and archaeology for 3D geometric information and conservation of historic buildings or excavation sites. Furthermore, it is also known to be well suited for documenting historic churches and ecclesiastic-like artefacts. (El-Hakim *et al*., 2004; Grussenmeyer *et al*., 2008a; Grussenmeyer *et al*., 2008b; Ikeuchi and Miyazaki, 2008) as shown in figure.3.

Figure 3: Different renderings (wireframe, shaded and textured mode) of a surveyed and modeled underground church. (Remondino, 2011).

Another example is a prehistoric stela dating back to 2800–2400 B.C. found in 1992 by H. Nothdurfter beneath an altar of eighteenth century church in Laces, near Bolzano (Italy). These stela are stones modeled by man’s activity with some carved story representing their daily life activities, animals instruments and many others. The digital reconstruction of the findings in Laces was performed with a triangulation-based laser scanner (Remondino et al., 2009). Figure 4 below shows the scanned prehistoric stela.

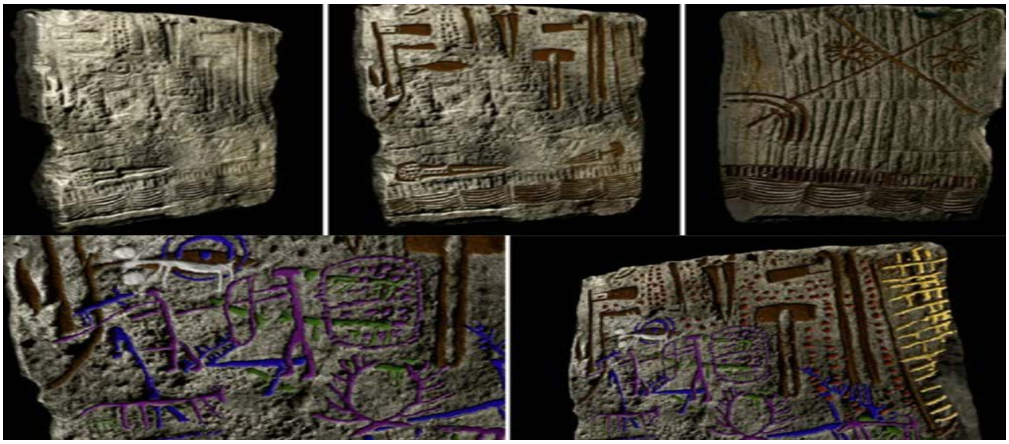

Figure 4: 3D modeling of the prehistoric stela (Remondino, 2011)

This system allows measurement of curvilinear elements that would be very difficult to measure by hand and capture the minute details of the structures with 2D drawings extracted from the point clouds as shown in figure 5 and 6 below.

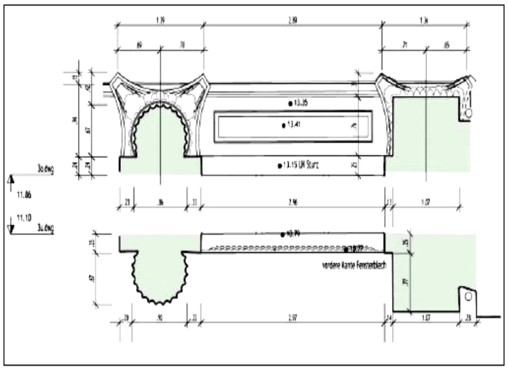

Figure 5: Orthophoto (3D Model texture) (Gadou *et al*., 2011)

Figure 6: 2D Horizontal section with high level of detail (Gadou *et a*l., 2011)

The advantage the system has over other methods such as photogrammetry is that, it creates 3D coordinates immediately (without time-consuming post processing) which are still subject to further evaluations (Gadou *et al*., 2011)**.** A large number of projects focusing on using this spatial technology for 3D modeling of heritage sites can be seen in literature. For example the work of Lambers *et al*.,(2007) performed 3D modeling of the site ground plan and stone architecture at Pinchango Alto, Peru, based on a combination of image and range data. In (Losier et al.,2007) 3D laser scanning was used as a substitute for generating 3D models from GPS positions taken at the top and the bottom of the excavation unit's boundaries. This technique allows for the quick and reliable measurement of millions of 3D points based on the run-time of reflected light pulses, which are then used to effectively generate a dense representation of the respective surface geometry (Al-kheder *et al*., 2009). For instance in figure 7, the main structure was modeled by image-based techniques, but parts of the surface containing fine geometric details was very difficult or impractical to model from the images, such as the enlarged section shown at the top left of the image. A laser scanner best acquires those parts (El-Hakim *et al*., 2003). In view of the above, 3D laser scanning also presents a future direction for researchers to enhance the quality of their 3D models.

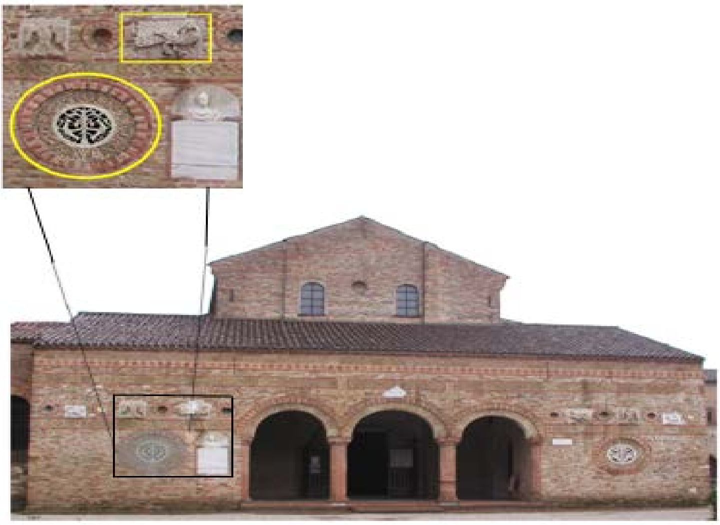

Figure 7: Scanned section on façade of the Abbey of Pomposa (El-Hakim *et al*., 2003).

The Need for 3D Laser Scanning Documentation for Nigeria Heritage Site

Geometrical information distribution of Nigeria cultural heritage sites is obviously limited since 3D laser scanning documentation has not been fully deployed. When utilized, the technology will help to increase public accessibility to the heritage sites, through visualization dissemination. This is considered so because the technology has the potentials to reveal some treasures that surround heritage sites given its high metric accuracy, visual accessibility and effectiveness in dissemination of artistic heritage (Guarnieri *at al*., 2010; Meyer *at al*., 2002). It also helps keep heritage from being forgotten, as it serves to communicate, not only to conservation professionals but to the public at large; the character, value and significance of the heritage. The technology can be used in structural or condition monitoring, such as looking at how the surface of an object or structure changes over time in response to weather (3D Laser Scanning for heritage, 2007). Furthermore, the technology is also appropriate for the production of 3D model animations and illustrations for presentation in visitor centers, museums and through the media (enhancing accessibility/engagement and helping to improve understanding). These together have point out the need to carry out a 3D laser scanning documentation on some heritage sites in Nigeria, which faced and still facing political neglect, developmental pressure, social unrest and climate change. The proposed heritage sites are the Benin City walls and moat, Ogiamen Palace, Deji of Akure Palace, Nana of Isekiri Palace, Isharun cave and Sukur Cultural Landscape. Detailed description of these heritage sites and the techniques to be employed are given below as follows:

Benin City Walls and Moats: The Walls of Benin are a combination of ramparts and moats, called *Iya* in the local language. In the past, it was used as a defense in the defunct Kingdom of Benin, now the capital of Edo State in Nigeria. Fred Pearce wrote in New Scientist that the Walls of Benin City was the world's largest man-made structure (Wesler et al., 1998). With more recent work by Patrick Darling, it has been established as the largest man-made structure in the world. They extend to approximately 16,000 kilometers in all, in a mosaic of more than 500 interconnected settlement boundaries covering 6,500 square kilometers and were all dug by the Edo people during the reign of kings Oguola (c. 1280 A.D) and Ewuare the great (c. 1440 – 1550 A.D).

Figure 8: Google earth showing some existing outer and inner portion of the walls and moat in Benin City Edo State Nigeria.

This heritage has hitherto been experiencing encroachment of various degrees because of the light penalties for offenders. The host community and the state government have recklessly encroach on this city walls and moat through human activities such as developmental projects, building constructions, farming, refuse dumps, excavation, erosion control etc.(Akabiemu,2003).

With the 3D laser scanning technology, the different views of this historic site can be fused together to form an objective data (raw data base of the site) that will enable a flying through showing the 3D geometry of the walls and moat. This can be achieved by firstly, using airborne Lidar to produce highly accurate Digital Elevation Models (DEMs) to identify areas requiring repair. Secondly a terrestrial laser scanner mounted on a tripod will be used to improve the terrain model, especially for surfaces covered with dense vegetation. The combined use of airborne and terrestrial laser scanner will produce DEMs with accuracies better than 10 cm. Also, the combined result will facilitate structural or condition monitoring, production of 3D models animations and illustrations for presentation. A similar work was carried out for the Great Wall of China (Zizheng *et al*., 2009) shown in figure 9. The combination of high definition, 2D photographs and 3D laser data of the Benin City walls and moats will enable straight forward and accurate reconstruction of the wall.

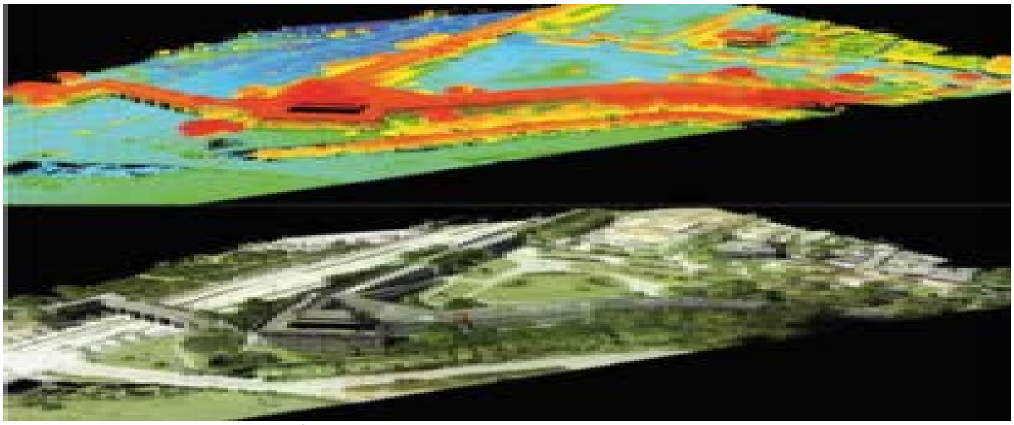

Figure 9: 3DLaser data of the wall, color by elevation (top) and color by SILC (bottom). (Zizheng *et al*., 2009)

Isharun Cave of Ashes. The Cave of Ashes as recorded by the State Information Technology Agency (2011a); Kolawole, Anifowoshe (2011) and Omosa (2012). According to them, it is believed to be the cradle of West Africa's oldest pre-historic man from where a skeleton dated to 991 years alongside other fascinating artefacts such as grinding stones and pottery fragments which dates as far back as 1000BC was excavated by Thurstan Shaw, an archaeologist. The ancient cave was acclaimed the original home of the people of Isharun in Ifedore local government area of Ondo State, in Western Nigeria. Parts of the skeleton of the man of the Cave of Ashes are kept at the University of Ibadan and Owo Museum of Antiquities, while a cast of the skull is in the British Museum of Natural History in South Kensington, United Kingdom: Perhapse The man of the Cave of Ashes confirmed the theory that man lived in West Africa before the Neolithic period, i.e before man started to settle in village groups (Adams Olorunfemi). Scanning the interior of this cave will definitely reveal amazing information since 3D laser scanning technology can be operated in total darkness as well as in daylight. Its principle facilitates interior measurement of caves and underground, as no additional illumination is needed. The dark cave can be modeled with 3D laser scanning since it offers rapid and high resolution method with which to map and model. The scan will enable the mapping of the existing natural and archaeological features within the cave and this can be related to excavations done outside. This procedure is in line with a 3D laser scanning documentation activity that was carried out on Wonderwerk Cave situated between Danielskuil and Kuruman in the Northern Cape Province, South Africa. The entire interior of Wonderwerk Cave was carried out for archaeological research as well as for historical documentation of the cave, rock art and the horizontal excavation grid which had been laid by the excavator (HeinzRu *et al.*, 2009).

Nanna of Itsekiri Palace: The architectural design of Nanna's palace in Koko, Delta State Nigeria has some semblance of renaissance or classical architecture, but was traditionally designed and constructed with local materials in its original built. However, according to its historical accounts, the over 106 year old building took four years to construct. Its construction began in 1907 and completed in 1910. The entire house was designed and built through direct labor by Nanna, his sons, relatives and slaves. The building accommodated Nanna and his household after his return from exile in Ghana following his overthrow after 1894 war by the British who invaded his original homeland; Ebrohimi in Delta State Nigeria.

Figure 11: Courtyard of Nana palace in Koko Delta State Nigeria.

The building is being used as a Living History Museum and declared a National Monument in 1996 by the NCMM Nigeria. In the past, this great heritage narrowly escaped destruction during inter tribal conflicts between two prominent ethnic groups in Delta State Nigeria. To avoid the erasure of the history of this building in case of unforeseen disaster, a 3D model will be beneficial for its documentation purposes, preservation, and future reconstruction purpose. This can be achieved by first defining all the scanning location in the interior and exterior of the building, and then the scanning exercise carried out combined with photographic imagery. The scanned results will produce point cloud with geometrical information that can be superimposed on the photographic pictures. This combination will produce an objective data base revealing a 3D geometrical model as shown in figure 12. A similar work was carried out for David Ben Gurion house in “Zar” street (Zalman Rivlin) 5 Northern City center Abraham hill, Ramat Gan, Israel (Rebeka Vital., 2013)

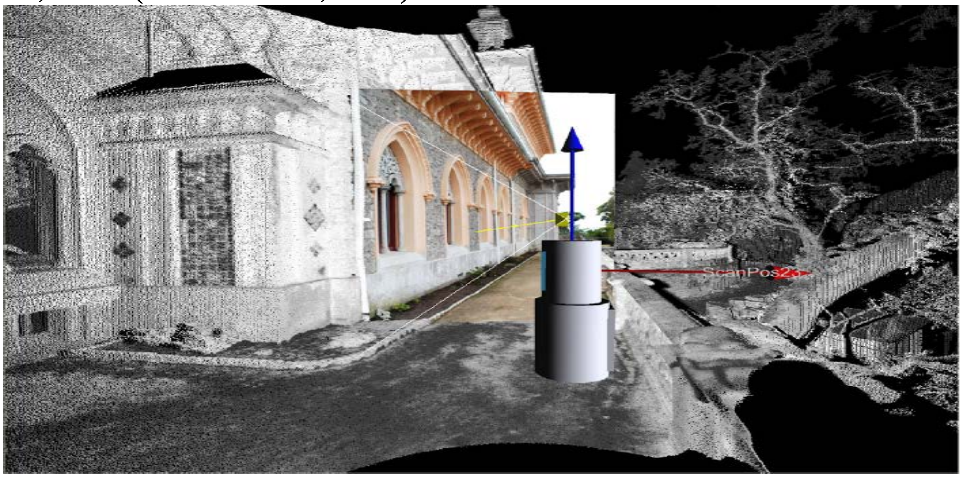

Figure 12: Point Cloud and Oriented Photo. (Oliveira et al)

Ogiamen Palace: This is a historic site located within the heart of the Benin kingdom in Nigeria. It is in the UNESCO tentative list of world heritage sites and a National Monument situated within the Benin City walls and Moat. The palace was built about 1130 AD with a great significance of being the only building that predate the emergence of “obaship” in Benin political history and the only building that survived the 1897 British expedition and siege. 3D digital preservation and recording on this site is indispensable as the activities of encroachers especially wood sellers, pose a great danger to its existence.

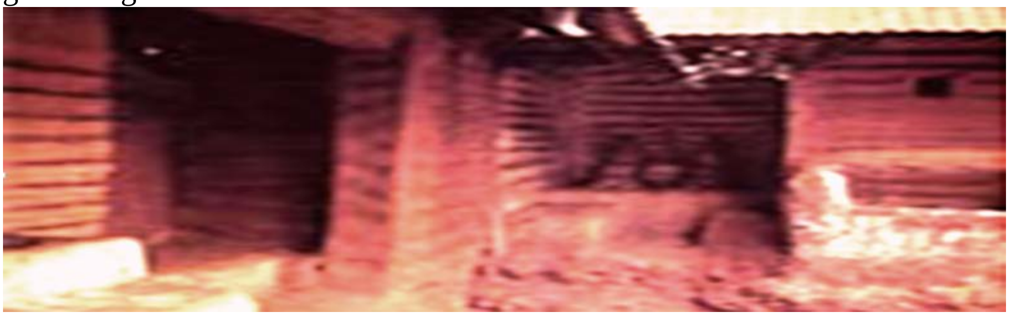

Figure 13: One of the courtyards of Ogiamen Palace, Benin-city Nigeria.

With documentation, using 3D laser scanner, the relevant artistic information about this palace can be preserved in 3D model and future damaged done to it and the surroundings can be reconstructed to a high precision. The technology will provide a better understanding of the elements of the building which would never be understood until the exercise is carried out as illustrated in figures 14 and 15. The scanned image has been able to distinctively reveal some element and geometry of this heritage.

Figure 14: Image (Heritage 3D, 2013).

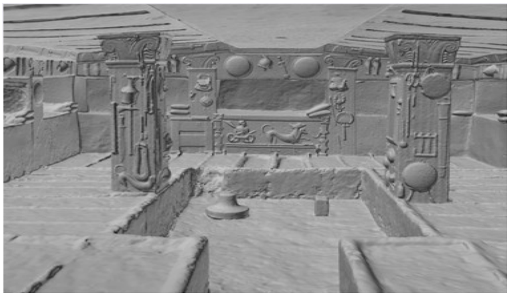

Figure 15: Scanned image (Heritage 3D,2013)

Deji of Akure Palace: The palace, a declared a national monument by the federal government of Nigeria, is situated in Ondo State, Nigeria. It is over seven hundred years old and has about twenty-two courtyards for ceremonial and living purposes. A fatal threat to this monuments results from the vibration of vehicles moving along the road close to the monument, resulting in cracks that clearly degrade the palace walls and structures.. A comprehensive study is needed to assess threats of this nature to ensure the palace sustainability.

Figure 16: Deji's palace Akure Nigeria.

A 3D model result from 3D laser scanner of this palace could serve as a basis for conservation and restoration policies and help to reveal more historical information about the inner courtyards that has perhaps never had access to sunlight since the palace was built.

Similar ideology helped the students of the University of Bielefeld during their project work to be able to detect the underground chambers (casemate) of the medieval castle for the first time in context Gadou *et al*., (2011). The high resolution of laser scanner used, made it possible to document the location and size of cracks that were caused by an earthquake several decades ago.

Sukur Cultural Landscape: Sukur Cultural Landscape is a UNESCO World Heritage Site located on a hill above the village of Sukur in the Adamawa State of Nigeria. It is situated in the Mandara Mountains, close to the Cameroun border. It is presently vulnerable to political and social unrest activities around its neighboring communities. This is a potential threat to its status and sustainability. The site whose terraced fields have been built with Local granite and defensive dry stone walls around homesteads, lacks 3D model information, peradventure there is a disaster occurrence, like the attack incident on the minaret of a landmark 12th century mosque in the northern Syrian city of Aleppo on the 24th April, 2013 (Surk.,2013). With 3D laser scanning documentation, the detailed elements of Sukur cultural landscape can be recorded monitored and space model of the entire landscape created in case of destruction from human conflicts.

Figure 17: Sukur Cultural Landscape.

Strength and Weakness of Nigeria Cultural Heritage Sites Documentation System

Documentation of cultural heritage sites in Nigeria is the statutory responsibility of NCMM. They acquire and maintain all the national cultural heritage sites in the country. Sites documentation process in the commission is a multi disciplinary exercise which involves the entire museum professionals. The attributes of its documentation system as stated by Bauerova, (2009), shows that, documentation should contain three parts: Text Documentation, Photographic Documentation and Appendix of Graphs and Other Illustrations**.** Subjecting the above first two categories to a SWOT (strength, weakness, opportunities and threat) analysis, reveals a better in-depth of the weakness and strength of the system in Nigeria as shown in the table below;

ISSUES	STRENGTH	WEAKNESS	THREAT	OPPORTUNITY
Text Documentation	Digitally done by UNESCO trained personnel	Not frequently updated with international standard.	Data format may be difficult to be read, sorted, indexed, manipulated, retrieved and communicated between different compatible and incompatible systems internationally	Expose heritage custodian to international and latest digital documentation technology.
Photographic (geometric) Documentation	There is 2D Photographic documentation of the heritage sites.	No 3D model, showing detail geometry attributes of the Heritage Sites, which means the visualization and presentation does not follow international standards.	In case of disaster, reconstruction of the affected site would be very challenging.	Encourage the training of heritage experts on Cultural Heritage 3D laser scanning technology.

The SWOT as illustrated in table 1 above has distinctively pointed out the deficiency of 3D model documentation and further strengthens the need for Nigeria cultural heritage institutions to encourage 3D laser scanning technology in her documentation system.

Conclusion

Cultural heritage sites are some of the most valuable economic and social assets any community can boast of. They are considered instruments for satisfying the demand for leisure activities and as such the onus lies on various state institutions to invest in its geometrical documentation using 3D laser scanning technology for proper preservation of their artistic information, and high precision reconstruction incase of future damage. This study has shown that 3D laser scanning can be used in accurate geometrical documentation to create a 3D model of heritage sites, especially in Nigeria. The write up as been able to propose some select Nigeria cultural heritage site that requires 3D documentation. This selected ones could serve as pilot project. In addition this study has shown how 3D laser scanning technology can be used to digitize information concerning heritage sites to robust digital library of spatial and non spatial material, relating to cultural heritage sites in Nigeria and West Africa at large. This further corroborates the urgency for all heritage custodians to speedily embrace the technology which is foreseen to be criteria for standard global documentation of heritage sites. To conclude, issues of cultural heritage documentation in Nigeria are a real, persistent and serious problem that requires pragmatic measures for solutions.

Acknowledgement:

The author is highly indebted to China University of Geosciences (Wuhan) and National Commission for Museums and Monument Nigeria.

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