CLOSE-RANGE 3D LASER SCANNING FOR ARCHAEOLOGICAL ARTEFACT DOCUMENTATION

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ABSTRACT
The digitalization of archaeological properties in this modern day has opened a new way for data sharing via desktop-based or internet, thus giving access to all researcher around the world to conduct their research. Nevertheless, the data must be in high accuracy and photo realistic as to ease the process of virtual analysis. Under this circumstance, a close-range three dimensional (3D) laser scanning method is indeed the best solution. Hence, this research is carried out in order to evaluate the reliability of Next Engine laser scanner in generating high accuracy photo realistic 3D model of archaeological artefacts. Bujang Valley, Malaysia which stored plenty of impressive historical complexes was chosen as the study area. The artefacts found during excavating the archaeological site were scanned to get their size, colour, characteristics and peculiarities which apparently are very important information that can help the archaeologist in performing analysis. Eventually, the final results showed that the close-range laser scanner offers rapid data capture and capable in providing high accuracy (millimetre level) photo realistic 3D model of the artefacts.

Keywords: close-range laser scanner, artefact, documentation

1.0 INTRODUCTION
Archaeological study is always concern with the conservation, restitution and preservation of the contrivances found in each research. Recently, changes have occurred in archaeology field due to major enhancement in terms of methodology, implementation of new legislation and the used of sophisticated computer technique for the purpose of archaeological documentation. Accordingly, advanced surveying technologies offer rapid, accurate and detailed documentation solutions on the physical characteristics of artefacts and the archaeology sites (Ergincan et al., 2010).

A three-dimensional (3D) laser scanning is a new technology which has proven to be well suited for a more efficient documentation in architecture, cultural heritage and archaeology field (Böhler and Marbs, 2004). According to Yildiz et al. (2009), a 3D laser scanner is a device that scan object to collect data on its shape and possibly its appearance. Laser scanning method, as proposed for the spatial data capturing process is differ from traditional methods, less complex recording and visualization techniques in that they provide metrically accurate data (Miri and Varshosaz, 2005). As suggested by by Simon et al. (2009) the implementation of close-range 3D laser scanning in the development of virtual museum has provides a variety of exceedingly precise and complex measurement tools than previously available with traditional measurements tools.

The revolution of artefacts documentation has brought tremendous achievement around the world. In China, a 3D photo-realistic model of artefacts have becoming highly in demand for interactive virtual exhibition. Instead of providing ways to share with the public, 3D laser scanning also facilitates virtual preservation and ease of data dissemination among researches because it provides real representation and highly accurate metric definition of an artefact (Simon et al., 2009). Besides that, the state-of-the-art of laser scanning started to be accepted by the community of Spain where it offers an innovative way of to capture and process information in the field of archaeology. Hence, this research was carried out in order to investigate the efficiency of NextEngine laser scanner, a low cost scanner in recording artefacts in Malaysia and finally give a highly accurate model with a good texture quality.
2.0 NEXT ENGINE 3D LASER SCANNER

2.1 Scanner Specification

3D laser scanning is a state-of-the-art technique which has been extensively used by archaeologist and historians to record artefacts for preservation and reconstruction of past civilization (Shaw and Devlin, 2011). In view of the fact that there are three categories of laser scanner: phase-based, time-of-flight and triangulation, the object to be scanned and level of detail required must be taken into consideration before choosing the scanner. NextEngine 3D laser scanner model 2020i is a desktop based laser scanner applying the principle of triangulation.

A triangulation-based laser scanner is commonly used in capturing small or medium size object. In this research, NextEngine laser scanner was used to capture every details and peculiarities of the artefacts and finally produced a digital 3D photo-realistic artefact model which can be used by archaeologist to conduct virtual analysis. With the price of 2300 USD, the scanner is provided with auto drive, part gripper, ScanStudio HD software and a toolkit that can help the lasers capture a shiny, dark and transparent object (Figure 1).

![Figure 1: A set of NextEngine 3D Laser scanner. From left: scanner, auto drive, part gripper, combination of all the things and the toolkit](image)

On the contrary with other close-range laser scanner such as Vivid 910i, NextEngine laser scanner is designed with a built-in studio lighting where the light will diffuse illuminators for shadow free imaging and provide wide colour range for excellent colour rendering.

2.2 Basic Operating Concept

As mentioned before, NextEngine scanner is operated based on triangulation principle. Figure 2 shows the basic geometrical principle of triangulation based laser scanner. Initially, a laser beam will penetrate a point on the object. Then, a built-in camera will detect the location of the corresponding point and measures it in their intrinsic space coordinate system (Tucci et al., 2011).

![Figure 2: Geometrical principle of triangulation-based laser scanners (Boehler and Marbs, 2002)](image)

Even though a triangulation laser scanner can give a high accuracy 3D model, the result is still depending on the distance between the scanner and the object itself. According to Pfeifer and Briese (2007), the quality of the intersection decrease with range. Indeed, the most basic and important thing in designing a triangulated-based laser scanner is the distance of the emitter and camera cannot be made too big for practical reasons. As a consequences, the range between scanner and object is restricted to one or a few metres and only small objects can be scanned by the scanner (Lesk, 2007).
NextEngine laser scanner is very particular about the size of the object to be scanned. Therefore, this scanner is designed with two cameras and two sets of laser with optics optimized for scanning (Strait et al., 2011). Correspondingly, user can change the scanning modes depending on the size of the object as long as it can fit within the field size. Nonetheless, object larger than the field can also be scanned via composite-captured and merged method. Table 1 describes the technical specifications and accuracy provided by NextEngine laser scanner based on the mode of scanning.

<table>
<thead>
<tr>
<th>Scanning Range</th>
<th>Macro</th>
<th>Wide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field size at the ideal distance</td>
<td>130 x 97 mm at 165 mm</td>
<td>345 x 258 mm at 460 mm</td>
</tr>
<tr>
<td>Depth of field</td>
<td>128-230 mm</td>
<td>384-563 mm</td>
</tr>
<tr>
<td>Geometric resolution (point density)</td>
<td>200 DPI</td>
<td>75 DPI</td>
</tr>
<tr>
<td>Texture resolution</td>
<td>400 DPI</td>
<td>200 DPI</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±0.127 mm (16 points/mm)</td>
<td>±0.381 mm (6 points/mm)</td>
</tr>
</tbody>
</table>

3.0 3D MODELLING OF THE ARTEFACTS

3.1 Types of Artefacts

There are various types of artefacts found during excavating an archaeological site. In Malaysia, the artefacts can be in the form of utensil, ancient water container, ornament, beads, keris and even skulls. Since the research area is located in Bujang Valley; which previously a well-known entrepot and ancient civilization, numerous kind of artefacts from China, Britain and Netherland can be found there. As mentioned before, the colour, texture, material and base-relief are the most important information needed by archaeologist in order to know the origin and technology exist during the production of the artefacts. Three types of artefacts with different types and surfaces were scanned to evaluate the capability of Next Engine in doing such task. The artefacts are shown in Figure 3.

![Artefacts chosen to be scanned; from left: copper container, piece of silver Buddhist and a skull](image)

3.2 Scanning Process

Scanning using NextEngine scanner is quite a straightforward procedure. Basically, the scanner was set up together with the laptop, auto driver (as a rotary plate) and part gripper (for aligning and stabling the object). Figure 4 (a) illustrates the setting up of NextEngine scanner. Next, the object preparation was carried out where dark and shiny surface object was enhanced with tools provided to help the lasers capture the data. The artefact was then placed at the part gripper. The position of the scanner can be manually adjusted until the artefact fit in the scan window. In addition, user can also adjust the scanning range either Macro or Wide. ScanStudio HD software was used to set the scanning mode such as scanning angle, scanning range, speed, and object's surface type (Figure 4 (b)).

![Setting up NextEngine scanner. Customize scanning setting window](image)
3.3 Point Cloud Processing

With the intention to generate 3D model of the artefact, the point cloud which in the .scn format was processed using ScanStudio HD software. Fundamentally, the data was trimmed to delete unnecessary points which were not belong to the artefact. Usually, there will be more than one set of scanning data for an artefact with different angles in order to cover the whole artefact. The scanning data must be combined to get a perfect 3D model of the artefact. The process of combining several scanning data is called registration or align. In ScanStudio HD, at least three common points (can be identified in both scanning data) must be marked on two contiguous scanning data. The process of aligning become easier where user can view the data with the colour. The next process is merging all the registered data. Merge or fuse is a process of combining the registered scanning data into one surface. This process will allow the model to be measured and view as one scanning data. Smoothing and fill holes process is performed to create the polygon data for the surface that has no data (holes) to get a complete surface model of the artefact.

4.0 RESULTS AND ANALYSIS

There are few types of 3D model that can be generated from ScanStudio HD; textured model, shaded surface model, meshed model and point cloud model. The textured model is a combination of a surface model with the image. The process of generating textured model was automatically done by the software because there is a function called geometry-locked image during data collection process. Table 2 shows the 3D model of the artefacts in various form. The accuracy achieved is 0.01 inch or equivalent to 0.25 millimetre respectively.

| Table 2: 3D model for different types of artefacts |
|-----------------|-----------------|-----------------|
| Copper Container | Piece of Silver  | Skull            |
| 3D Surface Model | 3D Point Cloud Model | 3D Textured Model |
5.0 CONCLUSION

The implementation of 3D laser scanning in the field of archaeology has brought several benefits such as increased measurement precision, ability to reconstruct artefacts and reunite collections and ease of investigation around entire object with possibility of sustained views at difficult angels. 3D modelling of artefacts has becoming the best solution to replace the conventional two-dimensional (2D) documentation especially when very complex and irregular objects like sculptures are to be documented. NextEngine laser scanner is an effective technology that can gratify the need for high-accuracy model and level of details with limited of time. The introduction of laser scanning technique in collecting archaeology data can be a booster towards rapid exploration of new archaeology sites in Malaysia. Laser scanning technique used in capturing archaeological data are more practical, less complex to handle and provide metrically accurate data which is highly significant for architectural, historical and other scientific research as well as for conservation and restoration purposes. Additionally,

REFERENCES


