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# 3D IMAGING TECHNIQUES IN DOCUMENTATION OF CULTURAL ASSETS IN MALAYSIA

Harlina Md Sharif[1], Hazman Hazumi[2] and Nurfarhanah Saedin[1]
[1]Department of Applied Arts and Design, International Islamic University Malaysia, Kuala Lumpur, Malaysia
[2]Department of Architecture and Sustainable Design, Universiti Tunku Abdul Rahman, Selangor, Malaysia
E-Mail: msharlina@iium.edu.my

## ABSTRACT

Despite worldwide rapid development in 3D imaging technologies, documentation of 3D cultural assets in Malaysia is still very much reliant upon conventional techniques. There is very little progress towards exploring new methods or advanced technologies to convert 3D cultural assets into 3D visual representation and visualization models that are easily accessible for information sharing. Shortage of expertise in many levels of digital practice and general perception that 3D digital documentation is costly and requiring high investments further hampers digitization efforts. In recent years, however, advent of computer vision (CV) algorithms make it possible to reconstruct 3D geometry of objects by using image sequences from digital cameras, which are then processed by web services and freeware applications. This paper presents an initial stage in an exploratory study that investigates the potentials of using CV automated image-based open-source software and web services to reconstruct and replicate cultural assets. By selecting an intricate wooden boat, *Petalaindera,* this study attempts to evaluate the efficiency of CV systems and their suitability to be adopted in digital heritage practice in Malaysia. By presenting a brief overview of previous 3D digital documentation efforts undertaken in the field of cultural heritage (CH) in Malaysia, the final aim of this study is to compare the visual accuracy of 3D models generated by CV system, and 3D models produced by terrestrial long-range scanner and structured white light systems. The final objective is to explore cost-effective methods that could provide fundamental guidelines on the best practice approach for digital heritage in Malaysia.

**Keywords**: 3D imaging, digital heritage, computer vision, cultural heritage.

## INTRODUCTION

Cultural heritage, as defined in Article 1 of UNESCO Convention 1972, is “architectural works, works of monumental sculpture and painting, elements or structures of an archaeological nature… which are of outstanding universal value from the point of view of history, art or science”. As such, cultural assets are tightly linked to a nation’s self-respect and identity. They record the movements of materials, technology and wisdom. They narrate the changes in society’s achievements, taste and lifestyles. Safeguarding the cultural assets is critical as they are material evidence of the footprints left by our ancestors. In the event of loss of these crucial records, history can be reinterpreted and even rewritten.

The awareness of documenting for future generations has brought about exploration of new methods that are more sustainable. There has also been an increased recognition that cultural heritage and its conservation is a shared responsibility of all levels of government and members of a community. Consequently, there is also a growing and persistent demand for more digital content of cultural heritage. The ultimate aim for digital cultural heritage information initiative is to enhance accessibility and to improve preservation.

The importance of digital heritage also becomes the main theme in UNESCO conference that took place in Vancouver in 2012 with its theme “The Memory of the World in the Digital age: Digitization and Preservation”. In its efforts to raise awareness and build capacity in addressing issues affecting digitization and digital continuity while developing digital preservation strategies that are sustainable and globally applicable. The conference underpins UNESCO’s concerns to protect, preserve and promote digital heritage worldwide.

The shift towards digitization of cultural assets, especially in Europe, is mainly propelled by the explosive increase in awareness among stakeholders. In the EU digital photography and image processing have become vital tools for conservation and restoration, based on a stream of research since the 1970s. The Victoria & Albert Museum in London has begun its digitization projects as early as 1996 [1]. The EU Framework Programme for Research and Innovation in its white paper has also addressed the critical importance of 3D and Cultural Assets as a range of activities to be incorporated in ICT research for innovation and policy support. The European Commission's Digital Agenda forms one of the seven pillars of the Europe 2020 Strategy which sets objectives for the growth of the European Union (EU) by 2020 [2].

## RESEARCH BACKGROUND

Despite rapid development of creative content in cultural heritage sector, progress in Malaysia pertaining to digital heritage is rather slow. Digitization is perceived as a cumbersome process given the range and amount of cultural assets that require documentation. Shortage of expertise in many levels of digital practice, from documentation, registration, digital asset management to output applications and visualisations further hampers significant developments in digitization efforts.

One of the major hindrances to Malaysia embracing the digital heritage shift is technological

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limitation. Although institutions such as the National Archives, National Library and National Museum Malaysia are currently very active in building their digital content and exploring initiatives to deliver the information, the digitization efforts are mainly confined towards converting paper-based artifact, such as manuscripts, to digitized paperless formats through scanning process. Documentation of 3D cultural assets is still very much reliant upon conventional techniques such as measured drawings and manual photogrammetry. There is very little progress towards exploring new methods or advanced technologies to convert 3D cultural assets into 3D visual representation and visualization models that are easily accessible for information-sharing and increased awareness of cultural heritage.

Digital documentation is also generally perceived as being “a costly exercise requiring high investments, not only a one time cost, but an on-going cost for the maintenance of the resources” [3]. A pioneering effort in a joint collaboration between the International Islamic University Malaysia (IIUM) and Lembaga Juruukur Tanah Negara (LJTN) in 2005 to digitize the Kampung Laut Mosque by use of terrestrial long-range scanner, despite getting recognition on national and international level, received poor response from local governmental institutions responsible for the stewardship of cultural heritage. The main hindrance has been the absence of a simple, user-friendly method for non-technical users to document and digitize cultural assets. Operating the laser scanner, not only requires technology know-how, it is expensive to acquire and requires a team of dedicated professionals working on the field for just a one-day survey job.

This paper gives an overview of 3D digital imaging projects that have been undertaken in cultural heritage sector of Malaysia, since 2005, using various technologies. The projects discussed here covered the use of long-range laser scanner, structured white-light scanner and CV systems employing a combination of freeware and low-cost software-driven systems such as AutoCAD 123D Catch, Silo 2 and Netfabb Basic. The artefacts documented have different size range as well as complexity. The output is in the form of visualization models and animations (for architecture), and 3D print for small and medium sized artefacts. This paper documents preliminary reports on the stages involved in 3D imaging, and potential benefits and limitations of such technologies for digital heritage practice in Malaysia.

## DATA ACQUISITION SYSTEMS

### 3D Laser Scanner

Two pioneering projects in the use of terrestrial laser scanner were the documentation of Kampung Laut Mosque (2005) and Istana Seri Menanti (2006) (see Figure 1). Both projects were carried out in joint venture with Geodelta Systems, the provider of Leica 3D scanner technology in Malaysia [].

The 3D laser scanner used in documenting Kampung Laut Mosque (KLM) was Leica ScanStation 2, a product of Leica HDS Geosystems. It claimed to be the most powerful and versatile time-of-flight laser scanner within its range. This portfolio of products becomes complete with Leica Cyclone, Leica CloudWorx and Leica TruView software, providing a full set of Leica-quality geo-referencing, surveying, and CAD integrated engineering tools for creating accurate deliverables and working with large scan data sets with unparalleled ease (Figures-2, 3).

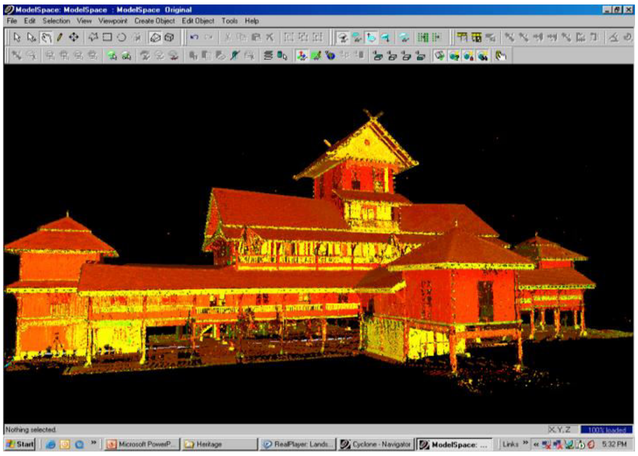

**Figure-1.** Cloudpoints from Istana Seri Menanti scan.


**Figure-2.** Leica 3D Scanner ScanStation 2 specifications.

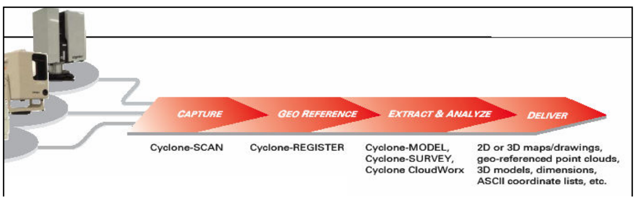


**Figure-3.** 3D Scanner workflow.

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The team documenting KLM was made of three parties: researchers from IIUM, a group of surveyors from LJTN and the operation consultants from Leica Geosystems. The first step was setting up the survey points that acted as geo-referencing systems. Then the building was scanned from various angles to get good mesh overlapping data (Figure-3). The datasets were registered in the form of cloudpoints giving true 3 dimensional form i.e. 3D model. This model can be ‘sliced’, manipulated, to retrieve plans, sections and elevations of the building (Figure-4, 5, 6).

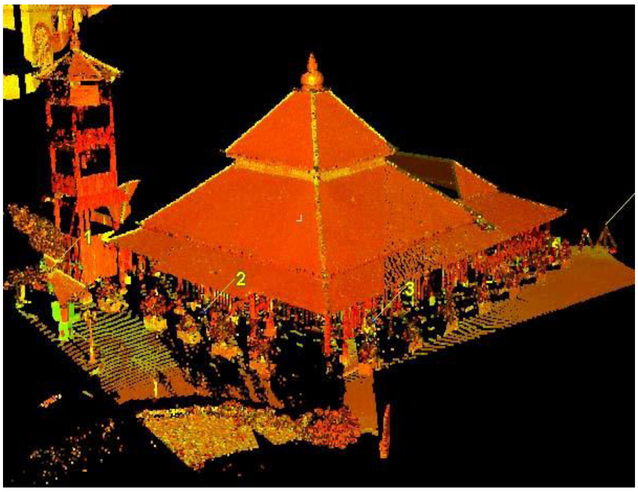


**Figure-4.** Scan data of KLM.

**Figure-5.** Data acquisition and registration.

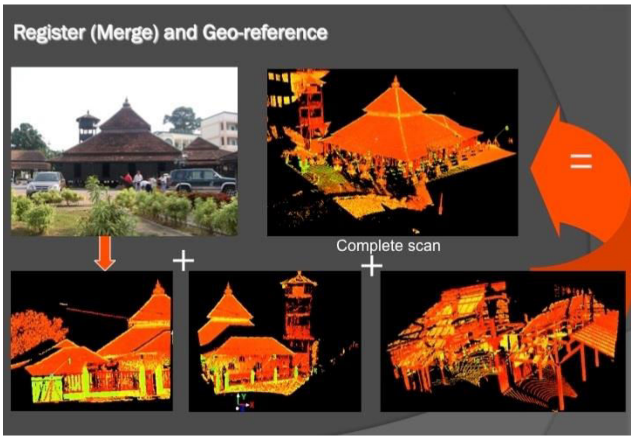
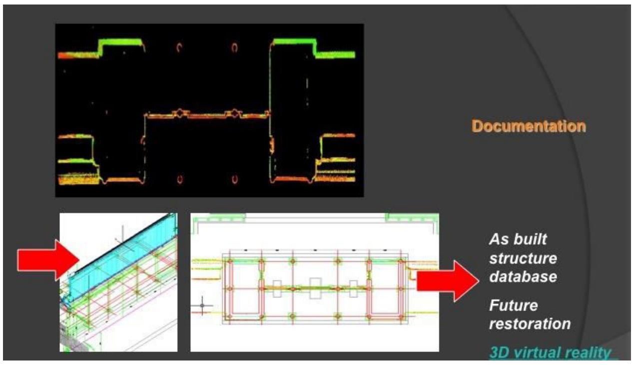



**Figure-6.** Registration and geo-referencing.

(a)




(b)

**Figure-7.** (a), (b) 3D scan process.

### Structured White-light Scanner

The main elements in this system are digital camera and a projector (Figure 8). Main features of structured white light systems are:

- Density point clouds (1,4 Million points / shot).
- Accuracy (~ 20 μm).
- Repeatability (~ 10 μm).
- Measurement time (2 – 5 sec).
- Possibility of acquisition of coloured point clouds.
- Possibility of combining with other techniques

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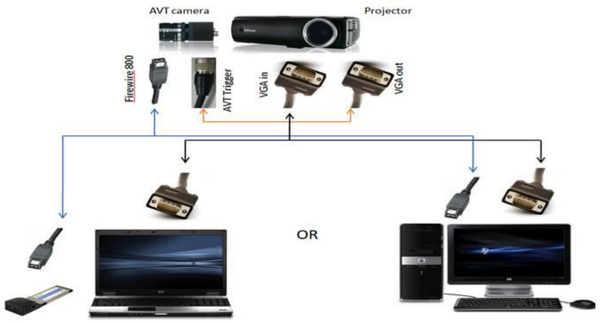


**Figure-8.** Connecting assembly for white-light scanner.

Data acquisition is performed by projecting a grid of light towards the object that is placed against a backdrop [4] (see Figure-9).

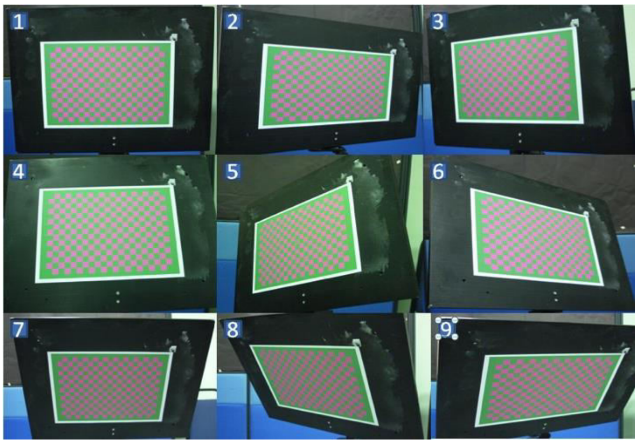


**Figure-9.** Calibration views.

The documentation exercise was originally carried out on samples consisting of 20 carving panels kept in the National Museum. The data acquisition and scanning process is as demonstrated in Figure-10.

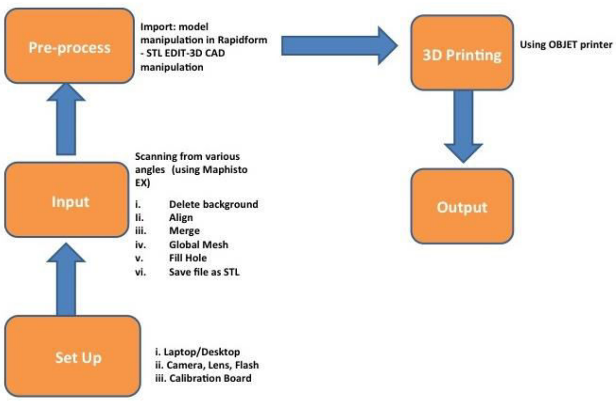


**Figure-10.** White-light scanning process.

In this exercise, a fragmented piece of woodcarving panel is scanned and then printed to get an exact replica of the original. This procedure does not only safeguard the integrity of a fragile artifact, as it encourages a "non-touch" approach, it reduces significantly the amount of time and procedures required to mend the artifact. Conventionally, restorers mend fragmented artifact by either gluing the fragments or by building specific support structures [5]. The process is as demonstrated in Figure-11.

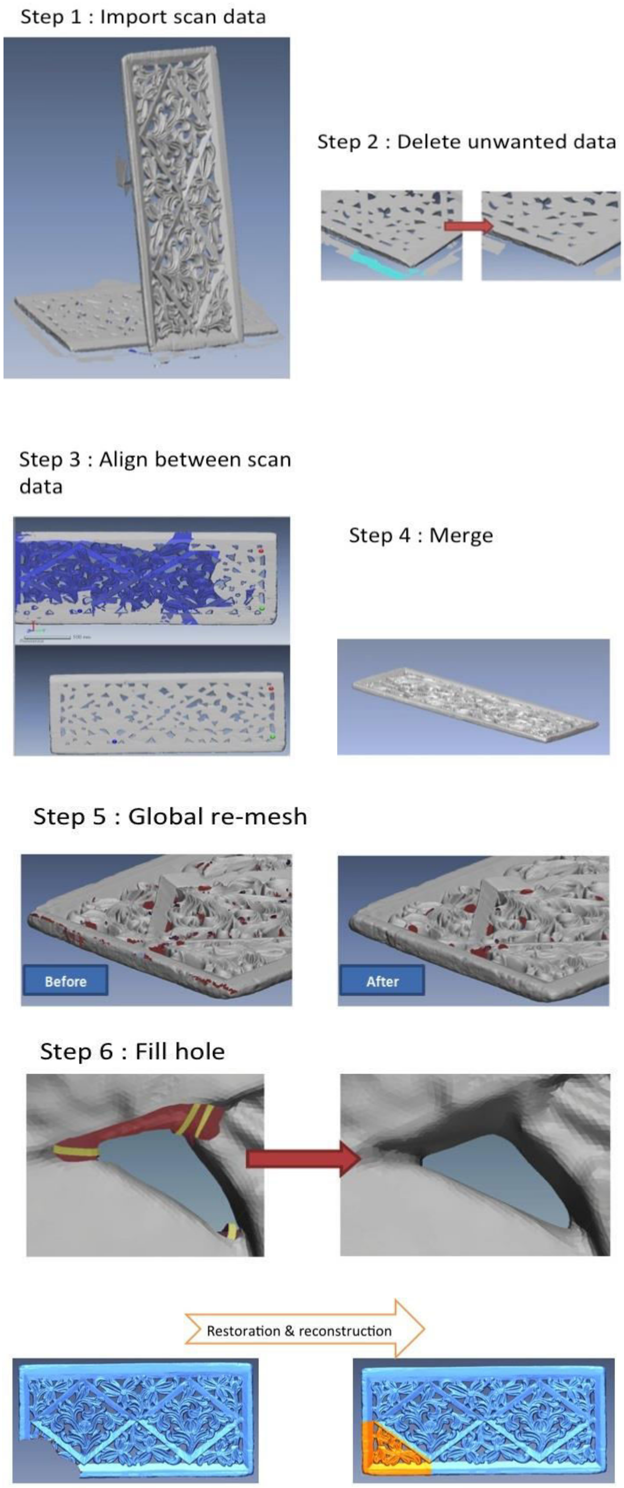


**Figure-11.** Steps in reconstructing fragmented artwork

VOL. 10, NO. 23, DECEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences



**Computer Vision Image-Based Systems**

The general workflow for image-based 3D reconstruction using low-cost systems is illustrated in the workflow diagram in Figure-12. The main steps involve capturing a sequence of images of the artifact by using DSLR cameras or an iPad (or any smart phones on Android and Apple).

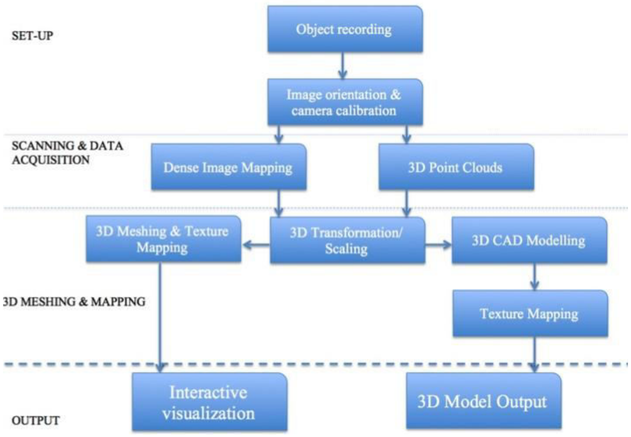


**Figure-12.** Workflow for computer-vision system.

For the purpose of this research, the Petalaindera boat is selected as a case study. This traditional boat is considered to be ideal due to its complexity and size (L: 4.66m H: 1.66m W: 0.95m). It is a colourful and carved wooden 3D motif of a male bird, with highly intricate detailing to the head and tail parts, incorporated into a fully functional ceremonial boat. With a head of a bird, during its use, it looked like a sculpture traversing the waters (see Figure-13).

**Figure-13.** The head of the bird Jentayu adorning the Petalaindera boat.

Due to its size, it is difficult to be handled and relocated without specialist transportations (see Figure-14). As a result, if it is not publicly exhibited, it will remain in hideous storerooms of the museums. Based on initial study, these decorative boats have ceased to be made as demand for them diminished alongside the change of Malay tradition and lifestyle.

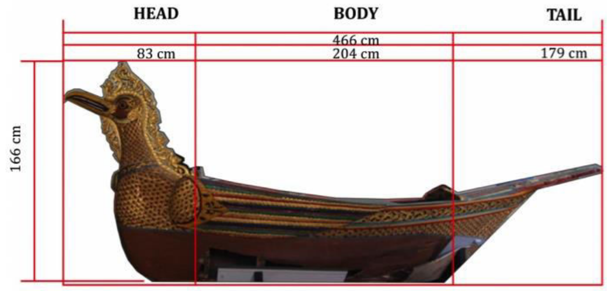


**Figure-14.** Petalaindera boat measurements.

Documentation of this kind of cultural asset is challenging for various factors. Taking photographs, sketches or measured drawings are insufficient to document the intricacy, colours, form and technology of the boat. Replicating i.e. copying the exact model by having craftsman produce an exact replica, is not only costly, it defies the main purpose of recording i.e. to record the ingenuity of the traditional design. Skilled craftsman can carve a similar but not an exact replica of the boat. Terrestrial laser scanner, despite its high accuracy, is more suitable to be used for long-range artefacts such as building and monument. Recent study of its application in documenting the lion sculpture at the imperial church in Konigslutter, Germany revealed that laser scanning registration produced gaps in complicated angles of the stone carving and geometry accuracy of the sculpture could not be obtained due to absence of reference data [6]. As such, it is crucial to search for a more viable and efficient method to document the Petalaindera.

In this exercise, the researchers used a mini iPad. At initial stage Autodesk 123D catch was selected. Due to complexity in getting an accurate capture of the boat, other software such as Silo 2 and Netfabb Basic were also explored. These systems are discussed below.

**Autodesk 123D Catch**

Autodesk 123D Catch is a freeware that provides automated service of 3D modeling from a sequence of images uploaded to its cloud. It uses algorithms from computer vision and photogrammetry and the performance of cloud computing that enables 2D images to be converted into a 3D model.

The modeling pipeline, from image capture to 3D model, is automated. The captured images were then uploaded to Autodesk cloud where modeling process was automated. Depending upon the object complexity, a 3D model will be generated within a relatively short time

VOL. 10, NO. 23, DECEMBER 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences



period. To get better quality meshing, or to get the model to be printed, post-modeling process is usually required. This involves stitching holes and imperfections in mesh quality. This process can be performed using open source software such as Meshlab [7].

The system is flexible enough to allow individual photos to be inserted into the model even after the initial modeling. The fact that the output can be exported into different formats means that further manipulation can be done using other freeware or low-cost software. Compared to using optical hardware driven scanners, CV systems offer flexible and cost-effective solution.

Modelling the Petalaindera using 123D Catch however demonstrates several limitations. One of the disadvantages of the 123D Catch is that it needs consistent lighting on the subject. The software cannot read or identify detailed model if it contents shadow. In addition, the study finds that the software needed 100% internet-connectivity in order to fully function.

**Silo 2**

According to its developer, Nevercenter, “Silo 2 is a focused 3D modelling application with the capability to smoothly switch between organically sculpting high-polygon models and precisely controlling hard-edged surfaces”. It functions in similar ways to 3D modeling packages such as SketchUp and 3D Max. It offers context-sensitive tools that allow a variety of selection and tweaking tools.

However the disadvantage of Silo 2 is that it requires external renderer. In addition, the software sometimes cannot read or identify missing parts of model. Figure-14 shows the missing parts of Petalaindera boat that made it unable to be printed.

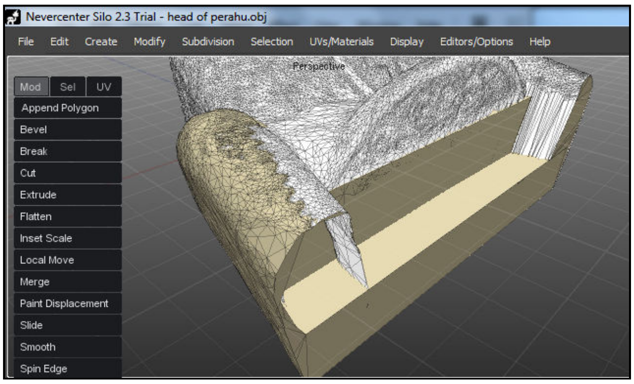


**Figure-15.** Petalaindera modelling using Silo 2.

**Netfabb Basic**

Before printing a 3D model from a stl file, it must first be examined for "manifold errors," this step being called the "fix-up." Examples of manifold errors are surfaces that do not connect, or gaps in the models. In this exercise Netfabb Basic is used to fix the modeling errors. Netfabb Basic is a freeware for handling of files in stl-format. According to its developer, Netfabb Basic is “not just a mesh viewer but includes an automatic repair and utilizes the same interface as Netfabb Professional” [8]. It is able to detect missing parts of 3D modelling before it goes to 3D printing.

The process of making 3D printed model of the boat began with digital documentation stage at National Museum Malaysia. Pictures were taken at 360 degrees angles of the artefact and only focusing on the head part of the artefact. The pictures were shot using iPad mini. Figure-16 shows the images captured of the Petalaindera.

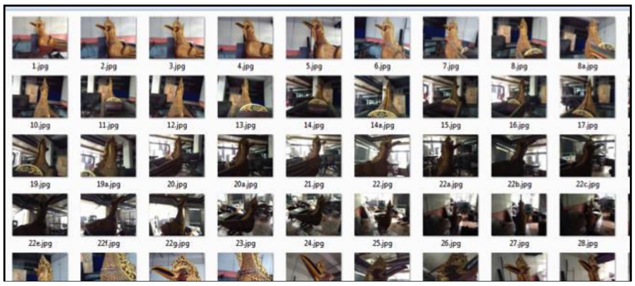

**Figure-16.** Images of Petalaindera Perahu.

The images were then numerically tagged to enable 123D Catch to read them. The images were then converted into 3D modelling as illustrated in Figure-17, while the red circle showed the areas that were not read by the software.

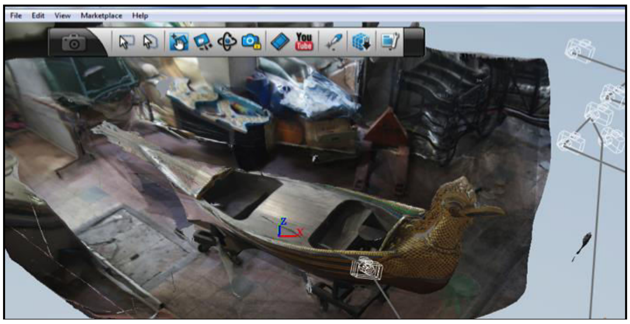


**Figure-17.** 3D model using 123D Catch.

The 3D model was then exported to Silo2 software as shown in Figure-18. The red circle indicates the area that was not read by 123D. Silo 2 was used to ‘stitch’ the defect surface. Figure-19 shows close up of 3D model after editing using Silo 2.

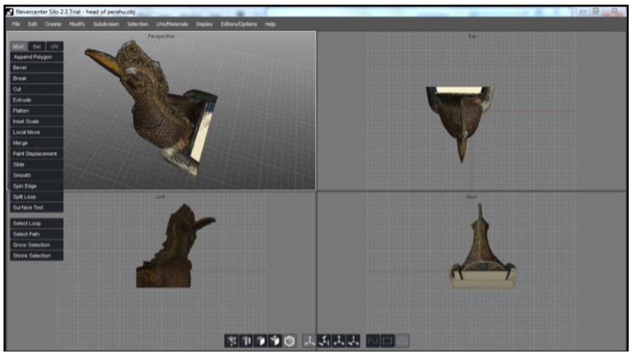

**Figure-18.** Head part of Petalaindera Perahu using Silo 2.

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences



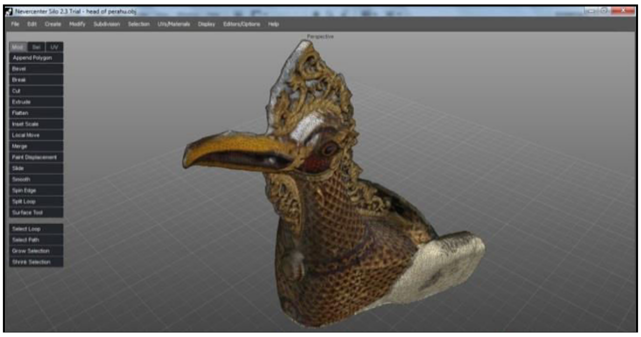

**Figure-19.** Close up of 3D model of Petalaindera.

Before using Netfabb, the 3D model was converted to 'obj' format. Figure-20 shows that the model contains the missing part and cannot be 3d printed yet. In Figure-21 shows that the model is still not solid represented, as represented by the red surface.

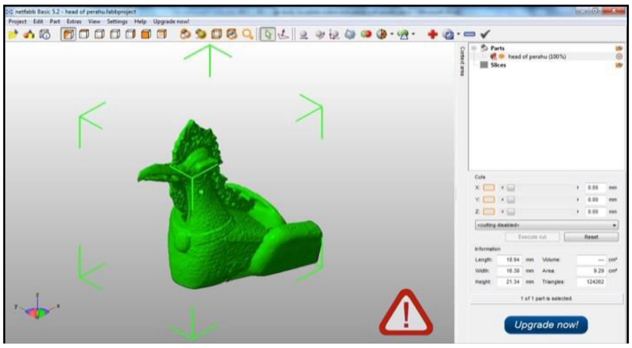


**Figure-20.** Petalaindera head using Netfabb software.

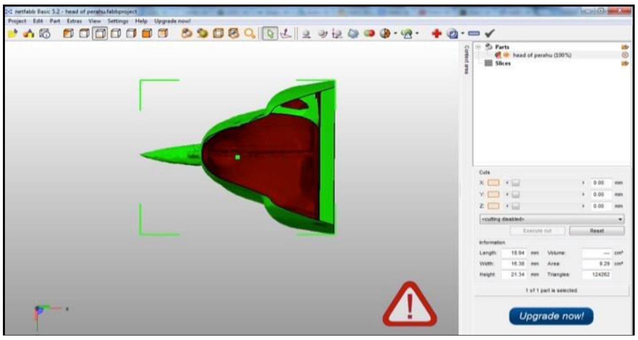


**Figure-21.** Error in 3D model.

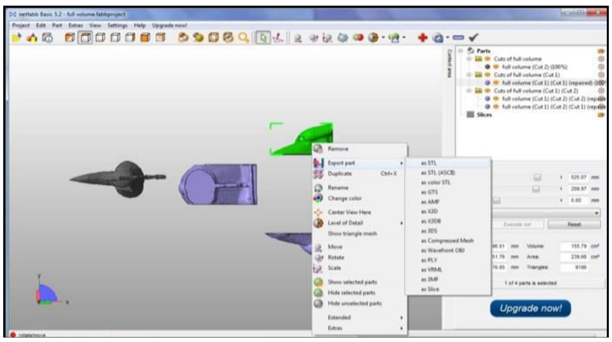


**Figure-22.** Editing the 3D model using Netfabb.

## CONCLUSIONS

In this preliminary report economical, image-based recording and modelling procedures, which are able to generate precise and detailed 3D surface models from terrestrial photographs for applications in architecture, cultural heritage and archaeology, were presented. The quality of results from image-based systems depends on the number of images used, the image resolution, photo scale, illumination conditions and the parameter settings of the software applied. The results from some software packages, using images from an iPad are actually quite comparable with results from expensive terrestrial laser scanners.

However, the reliability of the image-based systems requires improvement because some of the achieved results were geometrically unusable. Depending upon object material and lighting conditions, noisy point clouds were sometimes produced with 123D Catch. Compared to recent researches on the use of CV systems on CH assets, the preliminary results of digital documentation of *Petalaindera* demonstrated various limitations of the image-based systems. Due to the intricacy of this artifact; in terms of its overall size, form and detailing, the model produced lacks critical geometric accuracy.

Nevertheless, other researches performed on smaller and more rounded objects have shown promising potentials of CV documentation in CH [9-12]. Further investigations with a combination of other software-driven systems as well as other precise recording procedures such as fringe projection (structured light) or close-range scanners are necessary for small objects in order to be able to provide verified statements about the potentials available for cultural heritage assets.

Further research in this area is critical, as at present, the major obstacle of digitization of cultural assets in Malaysia is mainly cost and technology-related. The discovery of a cost-effective and efficient delivery system is crucial as it promotes societal awareness in the richness of the nation's cultural heritage. In addition, through digitization efforts, the inherited knowledge and wisdom can be easily researchable through online databases, thus making the collection and archival materials consisting of audio and visual data accessible to all levels of society.

## ACKNOWLEDGEMENTS

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