

A Study on Museum Artifact Digitization using Photogrammetry Method for Preservation and Design Education

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ABSTRACT

Photogrammetry is one of the 3d scanning methods for artefacts that can be said to be quite economical, when compared to other 3d scanning methods such as using a laser. This method allows everyone to be able to record digital visual data in sufficient detail. The use of 3d scanning photogrammetry has not been sufficiently optimized for artifact preservation and design education in Indonesia. Through this study, the researcher took several traditional West Java artifact samples to record data visual using close-range photogrammetry 3d scanning method. The results are divided into two parts. Part one are the evaluation of photogrammetry method that has been done. From this experiment, it is known that not all types of artifacts can be well documented by photogrammetric methods. From these conclusions, several recommendations were made for artifact documentation using photogrammetry method. The other conclusion is that it is known that 3D data is useful not only for preservation of artifacts in museums, but also for design education. Part two contains the alternative application of digital data from artifacts that have been recorded for their application in design science, especially product design.

Keywords: *Digital Artifact, Preservation, Photogrammetry, Design Education*

1. INTRODUCTION

Scanning 3D objects has been widely applied in Archeology field, especially related to visual studies and preservation efforts. 3D scanned archeological objects allowed researcher to deepen their studies without having to stay in a very long period to study an object. It is also, at the same time, enriched their documented digital data in other form than photos and videos. A. Gilboa, A.Tal, I. Shimshoni dan M. Kolomenkin^[1] said that 3D technology can be used to store, visualize and disseminate the entire geometric and textural information of object for scholarly purposes, educational projects and cultural resource management.

Currently the use of 3D scanning in the field of product design education, especially in Indonesia, has not been implemented optimally. Even though

Indonesia has a very long history of artifacts and also varies throughout the archipelago. Traditional artifacts in Indonesia have diversity in terms of manufacturing techniques, materials, and functions. By documenting and studying traditional archipelago artifacts, it is expected to enrich the knowledge of product design education.

The objective of this research to propose the utilization of photogrammetry 3D scanning process in 3D digital data collecting for design education. This paper will organized as follows. Section 2 provides the applied methods of photogrammetry 3D scanning process used in this research. Section 4 investigates the results of 3D scanned sample artefacts. Section 5 explores the possibility of proposed utilization methods of digital data collected, in Indonesia case of design learning. Finally, a summary analysis is presented in Section 6.

Photogrammetry is the science of extracting reliable measurements from two dimensional (2D) images, usually photography [2]. The process involves taking overlapping photographs of an object, structure, or space, and converting them into 2D or 3D digital models. Photogrammetry is often used by surveyors, architects, engineers, and contractors to create topographic maps, meshes, point clouds, or drawings based on the real-world. There are two primary types of photogrammetry: aerial and close-range. In this study, the close range photogrammetry method was used because the scanning objects have varying sizes (small to large).

2. METHODS OF PHOTOGRAMMETRY 3D SCANNING

The basic principle in photogrammetry is to arrange the 3-dimensional digital form of an object by reading the coordinates and geometric shapes. The number of photos that need to be taken from one artifact around 100-200 photos. (because we need at least two or three angles to construct an ideal image (frog view, eye level, bird view, top view, details, etc). Each angle should cover 360° view of the products, so for every 10° view turns, the total images provide on each angle approximately 36 photos, multiplied with how many elevation the camera will take photos).

G. Tucci, D.Cini and A. Nobile [3] conducted almost the same research and arranged a trial and survey process of the 3d scanning method before recording in the museum. Therefore, we conducted a trial first to find out the stages and supporting equipment that needed to be used. The basic stages of photogrammetry are starting from Recording, Pre-processing, Orientation and Measurement & Analysis [4].

The first stage starts from Preparation; namely the selection of artifacts and preparation of tools & settings according to artifact needs (including preparation of support/holder to keep object on its position and orientation (e.g. tack it, double tape, clamp, etc.). Then, the placement of each element of the equipment (table, background stand, photography background, rotating plate, tripod, camera, lighting, etc.) corresponds to its position (Control points). The second stage is Recording Scanning; adjusting targets for various photo points of view to get best shape of artifacts and increasing the accuracy of photos (Object point orientation & image recording). The third stage is Pre-processing; sequence numbers in the photo data collection and deleting unnecessary result (blurred image, fallen object, disoriented view, etc.). Then the fourth is Processing; detect and dispose of visual

elements that interfere (error), usually appearing as shadows attached to objects or display aids then import all the two dimensional images/frames into photogrammetric software to be generated / constructed. The fifth stage is Measurement & analysis and finishing; the software will estimate the position & orientation of point cloud (collections of 3D points that construct/resemble the final object), human/user should rectificate the misplaced point if needed. To get a solid, perfect, and precise mesh/3d model, human involvement is crucial and important in this phase. We need to clean the model, patch the holes, and do other final finishing. The sixth (final) phase is exporting; after the 3d model finish edited, we can export it to further usage (animation, 3d print, assets, etc.).

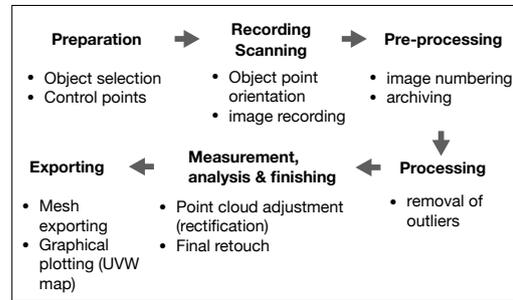


Figure 1 The photogrammetry schemes

The object reconstruction from photographs requires various supporting elements. This include all elements which contribute to this process, such as light sources, properties of the surface of the object, the medium through which the light travels, sensor and camera technology, image processing, film development and further processing [4]. Following are the specifications of supporting devices needed for close range photogrammetry method.

Table 1 Support for Photogrammetry Method

Close Range Photogrammetry	Explanation
Hardware	<ul style="list-style-type: none"> • Table • Background stand • Green fabric • Semi-automatic rotating plate (10 degrees) • Camera (DSLR/ mirrorless) • Tripod • Lighting & softbox • Smartphone (as wifi connection to the camera)
Software	3DF Zephyr, full 3D reconstruction, single NVIDIA GPU support, basic exporting capabilities, basic editing tools
Size of object	Suitable for small & larger product
Scan method	Photographic scan

Cloud processing	Should be connected to internet (can be a threat of data collecting)
Advantages	<ul style="list-style-type: none"> • Scalable & support to any size of object (while the fixed machine has limitation on maximal object size) • More portable & mobile • Provide customizable 2D photo (details, etc) • Camera quality can be upgraded • More alternatives software to be used
Disadvantages	<ul style="list-style-type: none"> • No infrared scanning like the fixed machine • Manual orientation to object (can cause lack of precision) • Overlapped (messy) meshes because unstable picture capturing & point of view elevation

In order to get the standard photographic result, especially when recording tall products, background stand is needed to hold photography background. This will also helps Post-processing (editing/masking) easier because the background was uniform and less clutter. In this case, green screen used because it has more contrast colour with the object (with approximate size: 140 x 400 cm). Semi automatic rotating plate was built to support image capture from each side of an object and it rotated +/- 10° every 3 seconds. The rotating plate can support up to 100 kg object and scalable into larger dimension. Rotating plate make scanning work easier and more precise because photographer/ assistant did not need to rotate manually, less effort and more accurate.

Higher camera specification will result in better picture quality. Sharer individual image will provide better image mapping for the 3D model. No specific camera lens should be used, but the standard lens (50 mm) will suit because didn't provide distraction and any other optical difference with eye perception. Filter, effect and any other additional gear is unnecessary to use. More common/ natural the photography setting, more normal the 3D model result.

This research used 3DF Zephyr software because it has easy access to application (free license) compared to Autodesk Recap Pro (although Autodesk Recap Pro more professional and better performing in data processing), but prior payment is needed to purchase the license before using the software. Hopefully, software with free license such as 3DF Zephyr are easily used by the students to applied photogrammetry method. Refinement with other software such as Zbrush and Substance Painter may be needed to modify, optimize, clean up the mesh and textures.

3. RESULTS OF 3D SCAN SAMPLE ARTIFACTS

This research used three artifacts from Sri baduga Museum; namely *boboko* (rice container), ritual jug and *kujang* (weapon). Insights into the design elements of artifacts are needed in the process of developing a design, including modern design. Cultural values of artifacts, detailed artifacts, distinctive features of artifacts are inspirational in the design process. 3D digital results can be utilized in the rapid prototyping process to evaluate design development. The objects chosen have different shapes, functions, dimensions and material characteristics so that they can represent the scan results through photogrammetry method. The following is an explanation of each artifact and the scanning results.

3.1. Boboko Hoe from Sumedang

Boboko Hoe is one of the Sri Baduga museum collections from Sumedang. Boboko is a truncated cone that stretches up with a round surface. made of rattan arrangement and reinforced by "wengku" in the form of diagonal braid motifs. Diagonal woven models show sacral elements as a third form of vertical (sky element) and horizontal (earth element) [5]. This object is a traditional kitchen equipment used as a rice container or for sending food.

As a container, Boboko is a representation of a female body. The projection of the female body in boboko comes from waist shape to the chest or below it. Boboko's distinctive characteristic is the presence of curved lines on the outline of the container that resemble the curved lines of a woman's body [5]. The form of the boboko container has meaning in Sundanese expressions. The shape of the cube at the bottom has the meaning of behavioral perfection; cone shape means perfection of place; then the circle at the top means spiritual perfection. Boboko has various forms and is spread throughout Java, one of which is in West Java. Boboko was chosen as one of the case studies because it has historical values and cultural values in West Java.

There are many difficulties encountered in the pre-processing and processing steps, it was caused by lighting aspects and characters from dark-colored artifacts with corrugated texture in repetition. At the results of scanning, the shadow is still visible and difficult to be masked. Wicker details that contain dense repetition with very narrow space tend to result in general bump, not specific and sharp just like the actual object. The color, pattern and gradient are

successfully shown visually, the support of additional lighting make the object well-lit, showing the holistic shape in general. Some holes and bumps also constructed in 3D. The 3D digital model shows right proportion and volume according to the actual artifact object, since the model is not perfectly geometrical, but naturally bent.



Figure 2 3D digital model scanning result for Boboko Hoe

3.2. Boboko Hoe from Sumedang

This ceramic-based jar originated in the 14th century and one of Sri Baduga museum collection. This jar is said to be part of the ritual for storing water. The aesthetic value of this jar clearly has more meaning than its function. Based on the results of scanning, the texture and character of the ceramic can be identified / informed. The top (hole) of the jar is not visible to the bottom, causing a 3D model result as if it were closed (Fig.3). The color and gradation of the jars are quite clear, supported by the contours that appear on the jar giving information on earthenware texture and the depth of the shape of the jar (volume).

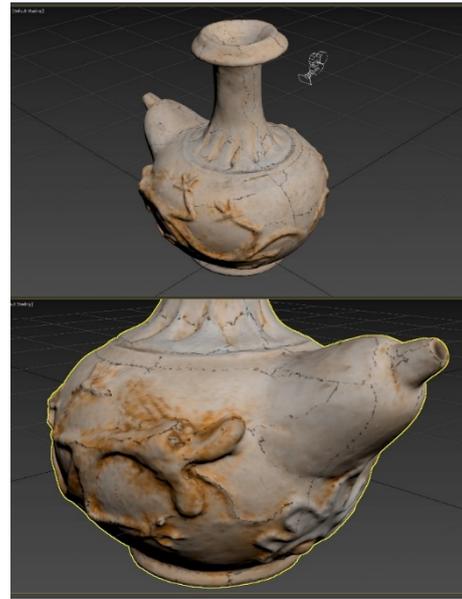


Figure 3 3D digital model scanning result for Ritual Jug

Compared to the other artifacts that currently scanned, this object is the best constructed. The 3d represent the actual shape, the gradient & texture mapped well, and less clutter or unwanted part. The hole can be edited with 3d software to remove / deform the clogged part.

From this shape we can see the transformation of ancient craft into nowadays product. Some elements remain the same (overall shape & dimension, ergonomics, etc.); and some elements are getting developed (carving/decoration can be more details with advanced utensils; thickness of product can be adjusted; materials can be more efficient, durable and variative; new functions and values are invented). The 3d scan process can provide natural projection & mapping that the start-from-zero 3d digital model will hardly accomplish (including the realistic mapping of material).

3.3. Kujang with Four Holes

In its development, kujang is not just a weapon, but being a “*piandel*” (a tool to increase self-confidence) and also a symbol to represent social status [6]. Kujang has many variations spread from various areas of West Java. However, the basic form has almost the same meaning. The shape Kujang is considered to resemble the shape of the human body and the dynamics of bird shapes [6]. The selected Kujang was one of Sri Baduga museum collection. Kujang consists of steel and iron material with a choppy texture and a kujang handle made from deer

horn. The first attempt of scanning Kujang turned out not really successful. The proportion of Kujang that tend to be more vertical than horizontal / balance, make the Kujang can not stand alone, it should be stood by other supporting part. Clay may be good idea, but it didn't hold the Kujang firmly. The object still fall every rotating plate turns, so we decided to put the Kujang horizontally.

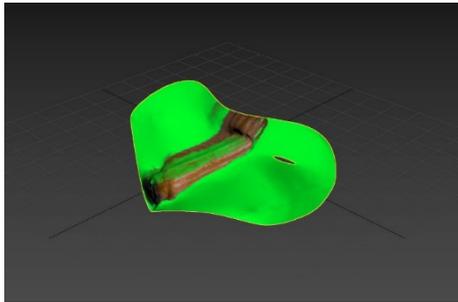


Figure 4 Unsuccessful 3D digital model scanning result for Kujang

The software detected the rotating plate as the part of the object, make the constructed 3d model deformed and misshapen. This problem can be solved with further masking to the image (removing the green screen manually and overall to each 2D images), or simply using another method (scan the object with standing position - not laid). In fixed machine such as NextEngine 3D Scanner, it has built-in supporting part that can hold the object on its place, but in this case we can't use the machine because the limitation of size.

4. DISCUSSIONS

4.1. 3D Scan Result for Preservation

In the previous research, objects that have been used for the scanning process are the collections of museum (in this case, the researchers use the collections of Museum Sri Baduga. As a state museum, the museum features various items related with the province of West Java, such as Sundanese crafts, furnishings, geologic history, and natural diversity). On the main area, there are standalone screens that can be seen in a strategic position but not functioned well (off condition). The 3D scanning result can be exhibited there (fig. 5a-5c). In a specific area inside the museum there is also a room that is prohibited for the public. Only specific and permitted guests are allowed to enter the room, one of the several reasons is to keep the product safe and reduce the interaction between human / visitors to the collection. With the result of digital scanning, hopefully the

people can at least see the picture in advance before they can enter or make an appointment to visit inside the restricted room.



Figure 5 (Left:) screen on the Ground Floor (main hall after entrance); (right:) screen on the Second Floor (collection room)

While corresponding with museum managers, the Indonesian Ministry already has a program to collect, save and preserve artifacts data, but it is confidential and cannot be publicly accessed. The Sri Baduga Museum itself already published a documentation about collection preservation in the form of a physical book. Until now, Sri Baduga Museum collections are not yet functioning for the public optimally because of the information given by the exhibition, both standing and temporary exhibition, are very short due to the limitations of the existing showrooms. According to the limitations, publication could fulfill the need of community or museum visitors to get information of museum collections. Inside this book, the profile of the collections is described in more detail and precisely, covering all historical and physical aspects, the use and the meaning of its collections on daily life from the creator's lifestyle.^[7]



Figure 6 (Left:) book cover of *Koleksi Pilihan Museum Sri Baduga*; (right:) a content from inside the book

In the future, the 3D model result can be integrated with the museum / government / global program according to the forthcoming trends, for example e-catalogue; interactive database; collaborative application or any manifestation of digital behavior that has becoming very familiar to our daily life and habit.

4.2. 3D Scan Result for Design Education

The result of this digitization process delivers a very wide range of benefits, including for design education scope. One of the several impacts and benefits from 3D scanning (including photogrammetric scanning) for design education are as follows:

- A. Understanding the product’s history or timeline and studying the aspects (including the interaction between products and humans; civilization phase; community status and all of the current conditions from the moment the product was made). By studying the past, designer not only avoiding and learn from the mistakes but also analyze the nowadays design and project how the design will be constructed in the future.
- B. Define the shape, material, details, accents and other technical elements from product, object or artifact to be studied and developed further.
- C. The impacts not only affected to one specific and particular study program, but also covers very wide range of field study, inclusive of industrial design, product design, craft design,

fashion and textile design, visual and communication design, spatial or interior design, architecture, digital design, even fine art (ceramics, drawing, jewelry or metalworks, sculpture, weaving, etc.).

If we take a case study, for example the curriculum at one of the design academies in Indonesia: Industrial Product Design Study Program, Faculty of Art and Design, Institute of Technology Bandung, we can acknowledge the syllabus or course study involve the advantage from the 3D scan result (digitization of objects, especially in this case: the museum’s artifact). The educational impact can be found as follows:

- A. *Sejarah Desain* (History of Design): The scanning results from museum artifacts are of course very influential directly to the “History of Design” course. Objects or relics that have been used by the past civilization are one of several important points in historical studies. Before touching or seeing the physical object, or even if the products are not available (extinct or vanished), this scanning result will be very useful and impactful for the study process. This data or materials can support the information regarding “the influence of technological developments and socio-political changes, the methodology of modern thinking that forms the background of a design”, suitable to the syllabus. Similar research programs or further development from other countries can support the richness of the data or materials.
- B. *Material dan Proses* (Material and Process): The artifact digitization process not only provides the shape and details for the object, but also texture, depth, including the color from the scanned product. With this capability, the 3D scan result will equip very much information about the material; production technique; joint system (if there is any); even finishing for some specific artifacts. From this object, students or people can analyze how the production process happened in that era; the material that is being used; current technology & industrial achievement, etc.
- C. *Ergonomi Desain* (Design Ergonomics): Unlike the results of 2-dimensional photography, the results of this digital scan are 3-dimensional, so the results can be seen from various sides. Including if the viewers have virtual simulation devices (such as VR or AR-player, Oculus, etc.), the files can be used from those devices or applications. By that usability, students can determine the scale

of the product to humans, even to the room. Some artifacts that interact directly with humans (e.g. handheld utensils; products that are used on shoulders; transportation equipment; farming tools; furniture and so on) can be analyzed for the relationship between products and humans and the work environment. Factors of safety, comfort, health, communication, convenience, work optimization (safety factor, comfort, health, communication, operability, and work optimization) can also be analyzed through the results of this scan

- D. *Tinjauan Desain* (Design Critics): Design Critics has a focus on critical review or evaluation of a design with the aim of producing new possibilities for future development. Various understandings of design theories are given based on the perspectives of cultural, socio-historical transformation, aesthetic values, semiotics, technological innovation, development strategies and political policies, and multi-disciplines. [8] Referring to this course explanation, 3D scanning results can prepare the object data to be studied and reviewed further for current design issue or futuristic discourse

Scalar variables and physical constants should be italicized, and a bold (non-italics) font should be used for vectors and matrices. Do not italicize subscripts unless they are variables. Equations should be either display (with a number in parentheses) or inline. Use the built-in Equation Editor or MathType to insert complex equations.

4.3. Professional Design Impact

Design Education not only affected or involved undergraduate study. On professional scope, design also plays an important role and the contribution of 3D scanning shows advantage in many aspects. For example, Tokyo National Research Institute for Cultural Properties also uses digital 3D scanning method to preserve cultural properties from several heritages around the world, including craftwork, historic buildings as well as intangible cultural properties such as traditional performing arts and local manufacturing techniques.



Figure 7 (Top:) photogrammetric survey for producing 3D data at Ta Nei Temple, Cambodia; (bottom:) 3D models in order to inspect past restoration works of outdoor monuments

The institute has been engaged in technical cooperation with the Authority for the Protection and Management of Angkor and the Region of Siem Reap (APSARA) on the conservation and sustainable development of Ta Nei Temple in Cambodia. [9] Through research, restoration projects and capacity development, it contributes to the protection of cultural properties of the world, mainly of Asian nations.

5. CONCLUSIONS

Design process requires model-making process to inform and confirm the design decision that made by the designer. Not only to inform the designer, physical model would also help user and client to understand, explore, and communicate what qualities a product has, and how a user should engage with it [10]. Traditionally, designer would make a physical model made of papers, clay, plastics, wood, and many other materials to represent their design concept and ideas. However, model-making process have been developed rapidly in line with advancement in technology. Designers utilize many ways to represent their ideas, ranging from concept sketches to more various physical forms, CAD, and virtual models. Milton classifies the design making process into six

categories; Sketch modelling, Mock-ups, Paper prototyping, Quick-and-dirty prototypes, Experience prototyping, Appearance models, Empathy tools, Bodystorming, and Rapid prototyping [10]. From the six categories earlier, this paper will focus on the Rapid prototyping process.

Rapid prototyping process allows designer to represents details of dimensions, form and textures of a design. Not only the designer should make the design with 3D modelling software, they can also utilize basic shapes, textures, or colors form existed materials library. 3D scanner capable of collecting various visual data that can construct digital 3D models., e.g. colour, texture, details, and accurate dimensions. Collected 3D data is very useful for digital modelling for designers. In designing a design that is related to the behavior and culture of society, designers need various reference data regarding design elements in cultural artifacts. 3D modelling of artefacts has becoming the best solution to replace the conventional two-dimensional (2D) documentation especially when very complex and irregular objects are to be documented^[11]. Through 3 D digital data of artifacts, designers can understand the value contained in the shape, function and material of artifacts. Therefore, 3D digital data is an important part of the design process.

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