Digital 3D Reconstruction and Simulation of Fragmentary Museum Artefacts: A Tiwanaku Incense Burner from the Ethnologisches Museum of Berlin

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Abstract. This paper presents a three dimensional reconstructive approach to the modelling of artifact fragments. An artefact from the collection of the Ethnologisches Museum of Berlin is examined: a fragment of a Tiwanaku incense burner with painted decoration. Rather than study the artefact in its current state, the visualization aims to show its initial state, i.e. the moment when it was used as an incense burner. Data from archaeology, material culture, indigenous aesthetics, and iconography were combined to determine the original appearance of the artefact and were visualized by using advanced modelling techniques. A computer simulation was performed, not only to show the vessel in the moment of its use, but also to illustrate the interaction between vessel's form and the smoke produced in an effort to uncover the aesthetics of Tiwanaku's ritual art. Additionally, the paper discusses both reconstruction and simulation as epistemological tools.

[digital 3D reconstruction, Tiwanaku incense burner, cultural heritage, digital archaeology, simulation]

Introduction

For several years now, digital 3D reconstructions have been successfully established as an instrument for the visualization of archaeological and historical finds in the research and preservation of cultural heritage. As a vehicle to visualize knowledge, they are of great importance for the broad accessibility of material and immaterial cultural heritage. Beyond the academic boundaries, digital 3D reconstructions offer a wide range of applications, especially in the context of museums to communicate information on artefacts, but also in publications, education, and, last but not least, in the commercial sector. They play an important role in the "translation" of scientific data by interpreting them in the form of a virtual model. In this manner, they contribute to a better understanding of certain aspects of cultural heritage and help to make complex scientific data accessible to general publics. Since they make the past, which is no longer preserved, focus of the scientific discussion, these reconstructions even permit testing working hypotheses (Forte and Siliotti 1997: 13).

Due to the further development of digital technologies, there has been an increased interest in digital 3D reconstructions of cultural artefacts since the turn of the millennium. The majority of the artefacts come from excavations (Hermon et al. 2011; Barreau et al. 2014), but there are also digital 3D reconstructions of museum artefacts as part of computer-based restorations (Kumar et al. 2003; Kampel et al. 2005; Kotoula 2009; Mara et al. 2010; Powell 2012; Amico et al. 2018). In many projects, the actual proportion of parts to be reconstructed is small and it is usually more a matter of transferring a real, well-preserved object to the virtual space than a reconstruction in the actual sense. In some projects, the focus is more on the demonstration of the technology used and less on the artefact itself. Some authors are therefore correct to complain that several visualizations do not meet the requirements of a reconstruction (Kotoula 2009: 433).

If the goal is to restore, fragmented artifacts or single fragments should be the focus for performing digital 3D reconstructions, and not the well-preserved artefacts of permanent exhibitions. So far, reconstructions of fragments have been rare because the proportion of hypothetical elements in highly fragmentary artefacts is higher than in

Fig. 1 Fragment, Ethnologisches Museum, Staatliche Museen zu Berlin, VA 16735; photograph: Martin Franken

slightly damaged ones, which until recently has been considered unsuitable for a scientific study as this is considered to affect the accuracy of a reconstruction. Recent studies have unveiled a new perspective on the research problem. Some authors (Bruderer in press), for example, point out that accuracy is already present when the hypothetical elements of the reconstruction are marked. This represents a new perspective on the creation of hypothetical reconstructions in which the concept of accuracy thus far has been associated with the degree of preservation. It has been considered as the most important precondition that dictates the level of accuracy. In this respect, the conclusion that the reconstruction is already accurate due to the marked hypothetical parts represents a new approach (Clados and Messemer in press).

In order to fulfill the already mentioned goals, and to test the hypothesis mentioned above, artefact VA 16735 of the Ancient Americas Collection of the Ethnologisches Museum Berlin was provided for analysis, thanks to the curator Dr. Manuela Fischer (fig. 1).

Research history

Eisleb (1980: 55) identified fragment VA 16735 as the head of a cougar (Quechua: puma), although the black dots visible on the snout more likely indicate the head of a jaguar. Also, the fact that spotted cats are often found in earlier styles of the Titicaca basin, for example in the Pucara style, makes an interpretation as a jaguar likely (Vetters 1993). Therefore, in the following, the feline head will be referred to as jaguar head and the reconstructed vessel as Jaguar Effigy Incense Burner, analogue to Alan Kolatas' term "Puma Effigy Incense Burner" (2003). The head was probably created by using a mold. Along with the quality of temper, paste and the elaborate paint, this information points to the assumption that the fragment was part of an incense burner that was created in a workshop in Tiwanaku's core region.

Posnansky (1957, III: 17, and pl. XXXIX–XLI) was one of the first who identified this vessel type as an incense burner and called it *Hiukaaña* (Quechua: sacred censer) or thymiaterium (Latin: incense burner). In Spanish, this type of vessel is generally referred to as *sahumerio* or *sahumador*. The insides of the vessels are often found blackened and sooty, which has led to the conclusion they were censers in pre-Columbian times (Young-Sanchez 2004: 53). They often have a base ring, which may have provided protection from the heat. Some of the vessels do not show smoke stains indicating they were produced only to be presented as an offering. Several scholars (Delaere et al. 2019; Janusek 2004; Korpisaari 2006; Wallace 1957) have argued that unlike the wooden or ceramic cup (Quechua: *keru*), which is frequently found in burial sites marking expansion of the Tiwanaku state across a very wide area, the presence of feline incense burners is one of the most dominant traits indicating the presence of Tiwanaku within the Lake Titicaca Basin. Such vessel types generally consist of a sculpted animal head (cougar, jaguar, *llama*) attached to one side of the vessel, and an erect tail on the other that also serves as a handle. Holes are also present in the undulated edge of the receptacle. All vessels are made of earthenware. They are often elaborately painted on both sides with identical (winged) profile felines, characters in Tiwanaku iconography that are not well defined.

Christophe Delaere (2019) and his team carrying out excavations at Khoa Reef, an underwater ceremonial location near the Island of the Sun in Lake Titicaca, Bolivia, have revealed deposits that consisted of killed juvenile llamas, various ornaments, and 37 ceramic feline incense burners. The sculpted heads of some of the incense burners are nearly identical to VA 16735 of the Ethnologisches Museum, making it very likely that VA 16735 comes from a ritual context on the Island of the Sun or nearby. Analogous to what Delaere and his colleagues (2019) mention regarding the Khoa incense burners, VA 16735 might have originated from a workshop within the same broad region.

Defining the original appearance

The jaguar head is fully preserved, while a large flange that originally surrounded the head is only partly preserved. The fragment was part of a Jaguar Effigy Incense Burner done in the Tiwanaku IV style and dating to the 6th–9th century, a time associated with the formation of the Tiwanaku state (AD 500–1100) (Bandelier 1910; Kolata 2003; Janusek 2008; Delaere et al. 2019). The container in which the substance was burned is not preserved and this part of the censer was considered to be the most uncertain feature in the process of reconstruction.

There are numerous objects of comparison in the Ancient Americas Collection of the Ethnologisches Museum in Berlin – VA 30852, VA 34847, VA 12283, VA 16703, VA 30829, VA 10599 (Eisleb 1980: figs. 6–11; fig. 2) to mention a few – that allow the accurate reconstruction of the missing parts. The most similar artefact to VA 16735 belongs to the Michael C. Rockefeller Memorial Collection of the Metropolitan Museum of Art (Acc. No. 1978.412.100) (Newton et al. 1987: 157). Similarly, the jaguar head is part of a flaring-side vessel that also forms the animal's body. Based on the incense burner of the Metropolitan Museum of Art the missing *keru*-like container of VA 16735 was probably painted and had an undulated edge. Different sources were used to determine the incense vessel's original appearance. Archaeological data provide valuable information on its compositional properties (paste, temper), production, provenience and original function; however, in the process of visual reconstruction, it was the iconographic analysis that contributed most to an understanding of the artifact's original appearance.

Of all Feline Effigy Incense Burners, artefact 1978.412.100 of the Metropolitan Museum of Art is not only the most similar to VA 16735, but also the best preserved incense

Fig. 2 Incense burner, Ethnologisches Museum, Staatliche Museen zu Berlin, VA 10491; photograph: Martin Franken

burner of the feline type. Although the bird wing markings on the face of the modelled head are quite different from VA 16735, the shape of both artefacts is nearly identical. For this reason, artefact 1978.412.100 of the Metropolitan Museum of Art was chosen as the main source for the visual restoration.

Iconographic analysis: interacting themes approach

To understand the function of the incense burner, all iconographic components need to be defined as completely as possible. Generally, Feline Effigy Incense Burners (and therefore also Jaguar Effigy Incense Burners) have two levels on which iconographic meaning can be discovered. There is, of course, the shape of the incense burner itself whose container, along with the head, forms the figure of a feline. This can be considered the main theme, which in the case of VA 16735 is the representation of a modelled full-figured jaguar. On the other hand, most of the containers are additionally decorated with motifs that are only partly related to the main theme. The paintings on the containers can be considered a secondary theme and often show characters different from the main theme.

Rayed Headdress

Originally, a large flange surrounded the head, which was painted with a motif defined as rayed headdress (Young-Sánchez 2004). Rayed headdresses of all kinds normally consist of “rays” that project horizontally and vertically, terminating in animal heads, plants, and concentric rings, an element Arthur Posnansky (1945, I: 113) identified as stars. Juan Carlos Quiroga and his colleagues (2019) described the motif as a seed of the

hallucinogenic Villca plant (Anadenanthera colubrina)[1]. The rays seem to indicate specific competences of the deities and to refer visually to their generative powers. In the case of the rayed headdress of the modelled jaguar head, black feline heads and concentric rings serve as terminators, which are still visible. Analogous to the rayed headdress on *keru* VA64431 (Eisleb 1980: pl. 83), the rayed headdress of VA16735 was completed by a feather element, which was probably originally painted between the concentric rings.

Characters: jaguar, winged jaguar

The sculpted jaguar head is part of the "full-figured" jaguar ("vollfiguriger" Jaguar) (Vetters 1993), one of the most frequently represented characters in Tiwanaku iconography. In vase painting it is always depicted realistically, with theriomorphic form, showing typical features like black rosettes covering the orange-brown body while black bands appear on the tail and legs. Dwight Wallace (1957: 66) already described the s-shaped ventral ornament as "dumbbell-shaped feline spots" like those found on a jaguar or ocelot. The modelled variety has the typical teeth of a beast of prey, and both sculpted and painted versions show a yellow disc hanging from the jaguar's neck. Similar to the feline motifs representing a cougar, the jaguar is sometimes shown in a standing or running position. This character is defined by the absence of wings and the presence of other elements that characterize the feline as a composite being. The only mythically charged element occasionally found is a rayed headdress, and a blue or green color of the fur (Posnansky 1957, III: pl. XIII.b, XIV.b, XXXIII.c). This clearly distinguishes it from the second character, which in its basic form is also a jaguar, but also has wings on its back and a downward facing tail. Missing evolutionary steps from the jaguar motif to the winged jaguar motif are a further indication that these are two completely different characters. The only feature both characters have in common is the occasional appearance of blue fur. A close look at the painted winged jaguar of artefact 1978.412.100 from the Metropolitan Museum of Art shows that the main color was originally blue-grey but faded over the time, which in turn has led to its mistaken interpretation as a cougar.

When analyzing image contexts, it can be said that each jaguar being is interacting with different characters. The full-figured jaguar seems to be connected with hunting topics when it appears in context with what Goldstein (1985: 122–124) calls the nesting eagle, or when it is shown grabbing birds by their necks (Young-Sánchez 2004: fig. 2.23). On incense burners made in the Qeya style (Young-Sánchez 2004: fig. 2.33), the jaguar is clearly connected with the Concentric Rectangle Motif (Cummins 2002), which can be probably interpreted as a cave motif (Clados 2018/2019), making this character related to ancestry and mountains. The image context of the winged jaguar is even easier to define. Artefact VA7824 of the Ethnologischen Museum (fig. 3) is one of the finest representations of the winged jaguar. This effigy vessel is made of a dark-blue stone engraved with trifoliate spots signifying (blue) jaguar fur. The winged jaguar seems to be associated with trophy heads (Posnansky 1957, III: pl. XIV.c) and the step motif (Smith 2011; Young-Sánchez 2004: fig. 2.26a), a mountain motif which is generally connected to supernatural beings of the highest rank like rayed faces or anthropomorphic figures shown in frontal view.

Workflow

As a first step photographs were taken from different angles. Several methods are available to transfer the artefact into virtual space, and researchers are trying to develop more

1 Also see Knobloch (2000) for an identification of this motif.

Fig. 3 Winged jaguar, effigy vessel made of blue stone, Ethnologisches Museum, Staatliche Museen zu Berlin, VA 7824; photograph: Martin Franken

efficient and effective methods. These modelling methods of small-scale artefacts are mainly categorized into two approaches: semi-automatic and manual. Many projects apply the semiautomatic approach and create 3D objects one by one with the support of technologies like photogrammetry and 3D vision. Artefacts are either scanned with a laser scanner or with a camera using digital photogrammetry. The manual approach is sometimes combined with the aforementioned method and is used to create all geometries of an artefact one by one in software packages. Both methods have their strengths and weaknesses. Both serve the purpose of documentation and can simultaneously serve as the basis and reference for the analysis. As many previous studies were based on the semi-automatic approach, the goal of the present project is to test the efficiency of the manual approach in the context of the 3D reconstruction of an archaeological artifact.

Although the manual approach does not automatically extract geometric information from photographs, many steps of the workflow are automated. In fact, the tools availa-

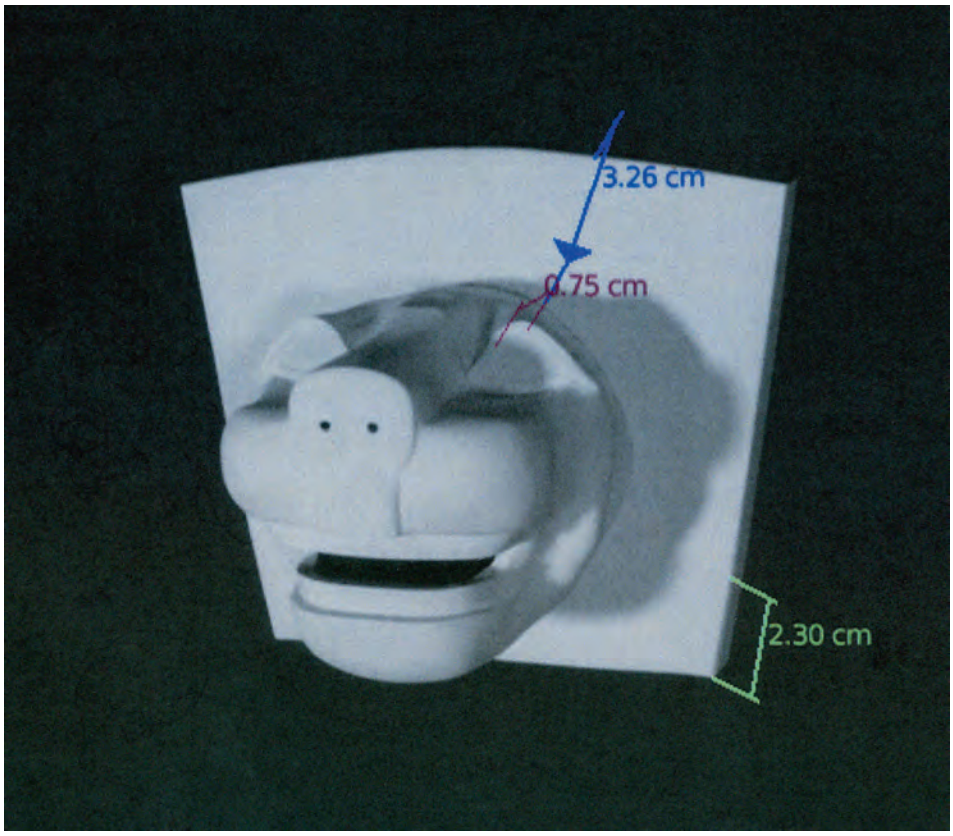

Fig. 4 True to scale model of the feline head; © C. Clados.

ble make it possible to create true to scale models. One definite advantage is that photographs do not have to be edited in advance to guarantee great accuracy; another is that it is even applicable when the real artefact is not accessible because the 3D object can be created by using photographs. When capturing a single fragment, the workflow was in many aspects very similar to what is presented by authors using 3D photogrammetry (Kotoula 2009). A uniform background, turntable, and DSLR camera on a tripod were used to take photographs. The item of interest was placed on a sheet of white paper. As VA16735 is an artefact with great volume, photographs were taken from three heights, then the object was rotated 180 degrees and the entire process was repeated. For modelling this kind of object various 3D graphic suites are available (Z-Brush, Maya, Cinema4D, Blender, Houdini, Autodesk Mudbox) that are very useful for any 3D visualization requiring exact measurements, including architectural projects and archaeological artefacts (fig. 4). Many are equipped with tools to display measurement information in the viewport, making the process of designing objects with exact dimensions easier.

Once the polygon mesh defining the shape of the incense burner was unwrapped to a UV map, a flat representation of the surface of a 3D model, the texturing process can begin. As the aim of the reconstruction was not to imitate the surface of the item, but to visually restore its complex iconography, texturing was done without the use of an image. Instead, only the paint mode tools were used, painting the mesh in the 3D View as well as onto the currently selected UV texture map. Colors were assigned based on the photographs. Various options were available to identify the hypothetical parts of the reconstructed incense burner. There are many ways to visualize uncertainties, for exam-

Fig. 5 Hypothetical parts marked with less saturation using Photoshop; © C. Clados

ple by giving the respective parts a transparent texture as part of the modelling process, however, in this project they were marked with less saturation using Photoshop once modelling was completed (fig. 5).

Simulation

The simulation turned out to be difficult because smoke simulation in many graphic suites only works well with simple forms. Therefore, the smoke plume had to be programmed as an emitter, so that a sufficient amount of smoke could accumulate in the hollow space to finally escape through the mouth (fig. 6). It has long been known that, when in use, smoke would have come from the open mouth of the feline head. However, the simulation showed that the amount and consistency of the smoke determine the flow rate and the form of the emission. This observation leads to two conclusions. Either a very strong smoking material had to be used so that enough smoke could be generated to also pass through the relatively small mouth opening, or the vessel was not

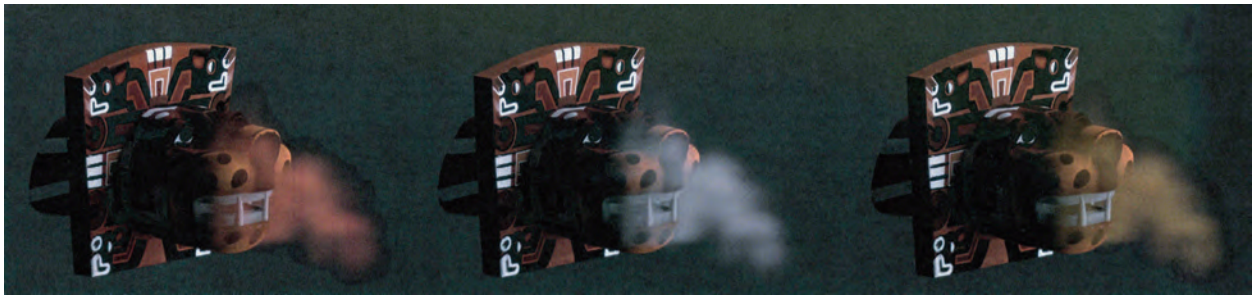

Fig. 6 Simulation of smoke escaping through the mouth: (a) red smoke, (b) white smoke, (c) yellow smoke; © C. Clados

Fig. 7 Overall appearance: interaction of incense burner and smoke; © C. Clados

intended to serve as a smoking vessel at all, but was created to be made as offering. The simulation also provided another useful aspect: for the first time, one had an idea of what the visual effect of the interaction between vessel and smoke would look like and what overall appearance was evoked (fig. 7).

Epistemology

In recent years, 3D reconstructions have not only become an important tool in the visualization of certain aspects of cultural heritage, they have also allowed existing working hypotheses to be tested and have led to significant insight. The idea of gaining knowledge from the actual process of a 3D reconstruction was already considered by Forte and Siliotti (1997: 13) and recently demonstrated by Clados and Messemer (in press) on two artefacts of different scale.

During the reconstruction process, a greater gain in knowledge is gained on different levels. While modelling, not only the actual shape of the container had to be considered, but also the reconstruction of the painted parts, which led to new information, for example with regard to the feline characters ‘jaguar’ and ‘winged jaguar’. The reconstruction also included an approximation of the original color intensity of the motifs, which gave insights into the aesthetics of Tiwanaku’s artists who favored brilliant colors. These aesthetics are often opposite to contemporary western aesthetics that, in contrast, strives for the reduction of color, and with regard to ancient sculptures, a monochrome-white antiquity. The reconstruction thus became a tool for iconographic research and style analysis. However, it is the simulation that conveys the most insight. When the Jaguar Effigy Incense Burner is used in the virtual world, smoke quickly spreads in the hollow space and forms a clearly visible cloud when it emerges (fig. 6). The impression that is created here is like the breath of a supernatural being. With less concentrated smoking

essence, a small amount of smoke comes out of the mouth and looks more like the natural breath of a jaguar. Also, the color of the smoke can change the meaning of the overall appearance. Different colors could have been used to generate very different meanings. For example, while white smoke might have looked like breath a red smoke could have been used to imitate blood. In addition, the simulation of a light and strong emission of smoke led to the question of whether the vessel was possibly interacting with the wind. In this case, the wind determines the course of the smoke, a simulation planned in the near future by the author.

Simulation and exploring worldviews

The simulation of the interaction of the incense burner and smoke produces an overall image that the ancient Tiwanaku artists probably also wanted to convey: a smoking jaguar. This event leads to the conclusion that the vessel was not meant to work as a piece of artwork by itself (*l'art pour l'art*) as has been common in Western art of the early nineteen century, but in combination with the natural elements. By this, the simulation provides insight into the worldviews of Tiwanaku society, which show many features of animism, i.e. the belief that objects, places and creatures all possess a distinct spiritual essence. This fits with the fact that the more recent Inca religion also shows clear signs of animism, often expressed by Inca imagery. When the incense burner was in use, when smoke rose over the undulated edge, this was nothing less than the re-enactment of a mythical primordial event, one that was definitely of central importance to the Tiwanaku state. It is up to future studies to define more closely a narrative that centers on the "smoking jaguar" in Tiwanaku iconography.

Final thoughts

The digital reconstruction of a Jaguar Effigy Incense Burner based on a fragment of the Ancient America's Collection of the Ethnologisches Museum in Berlin does not claim to be 100 percent accurate in relation to a reconstruction which is based on a very fragmentary artefact. The hypothetical reconstruction in color does not intend to illustrate an „authentic" image of an historical artifact; instead, it attempts to convey an idea of *Zeitgeist*. Western aesthetic perception concerning antique sculptures is enormously influenced by pigments fading and vanishing. Here a reconstruction acts as a corrective action that undermines the fixed perception of monochrome or color-reduced ancient sculptures. Depending on the data available, reconstructed form, motives and interpretation of its function can vary in many details, which does not reduce its scientific value, as long as the uncertainties are marked, and documented. There is a diverse field of possibilities, concepts and methods of how to communicate hypotheses. The decision of which option to use depends on several aspects, like the research question, target group, mode of presentation, state of the examined artifact, quality and quantity of source material. However, as previously demonstrated, 3D reconstruction is far more than a useful technological tool to visualize information on a certain artefact. It offers literally another perspective of existing facts, and, more importantly, it produces new ones which result from the very specific production process of a 3D reconstruction.

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