Virtualization and 3D Visualization of Historical Costume Replicas: Accessibility, Inclusivity, Virtuality

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Abstract. Digitization in cultural heritage has been established as an important method for research, preservation, documentation, and dissemination of knowledge. Largely this research has been done on archaeological sites and artifacts made of durable materials using a variety of 3d digitization methods, from digital photogrammetry to laser scanning to and structured light 3D scanning. One class of artefacts less interested by 3D visualization applications of that of ancient textiles. The perishable nature of these materials and consequently their limited availability in museum collections has not encouraged many studies, with the exception of some significant case studies of digital restoration and 3D capturing. This paper aims at critically revising the available 3D digitization and 3D visualization approaches for the study of ancient textiles and present an example of how such technology can be successfully used to achieve global digital dissemination of knowledge among the general public and that public affected by disabilities that can hinder the learning process. In the Spring of 2022, a team from the Institute for Digital Exploration (IDEx) at the University of South Florida (USF) scanned eight items from a collection of Minoan and Mycenaean garment replicas created by Dr. Bernice Jones, a unique collection, subject of several national and international exhibitions, that has become the primarily visual interpretative tool for the study of Minoan and Mycenaean fashion. Using structured light 3D scanning to generate accurate and realistic replicas, Augmented Reality (AR) and Virtual Reality solutions have been applied to create a digital companion for future exhibitions.

Keywords: structured light 3D scanning · Augmented Reality · Virtual Reality · accessibility · inclusivity

1 Introduction

The digitization of cultural heritage artifacts continues to expand and grow rapidly. Techniques of digital photogrammetry, laser scanning, and structured light 3D scanning are accepted methods of digitization of both archaeological

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sites and artifacts [17]. 3D modelling is also largely used to post-process the 3D data generated by those techniques and deliver results more suited for public outreach purposes [3].

Ancient textiles, however, profoundly differ from other classes of artifacts, due to their fragility and serious conservation issues, and for their study the usual digital methods are often applied from novels perspectives. 3D modelling protocols are used for the digital restoration of ancient textiles using dataset obtained via advanced image analyses [5], often in tandem with machine learning methods for automatic reconstruction of complex patterns [4]. Digital photogrammetry, according to a research study [18], is the most used 3D digitization techniques for the virtualization of historical costumes and ancient textiles for its main characteristic of generating highly-realistic digital replicas even of very intricately shaped examples [13]. Laserscanning technology is largely used in this case more to assess the capability of the devices on a challenging material than to generate new historical research [15], although the application of laser-based 3D profilometers to map the topography of woven fabrics, for example, bore significant results [14]. More promising are the application of structured light 3D scanning to case studies of historical or archaeological textiles. An attempt at establishing best practices in this case is the recent work conducted on the Emir of Bukhara's costume at the Samarkand State Historical-Architectural and Art Museum-Reserve in Samarkand, Uzbekistan [16], the first to illustrate a full methodology of practice and observations. Born as a test project to validate if structured-light scanning could be successful in creating 3D models of historic clothing, it focused on developing a comprehensive methodology to do so. While overcoming problems regarding display were improved on site, the authors of the research were still able to successfully complete the scanning within a limited time frame prior to the exhibition opening to the public. The main take-away of this seminal work is that, while earlier computer-aided design (CAD) projects were focused on manually modeling and had to determine appearance and apply it during post-processing, the use of structured-light scanning allows for the inclusion of this data, creating an accurate representation of the textile's color, texture, and overall appearance of the Emir of Bukhara's complete outfit.

While the effectiveness of the main 3D digitization and 3D visualization is unquestionable with respect to documentation and study of ancient textiles, less emphasis is given to the scientific literature on the potential that 3D models of historical costumes for public outreach. Against this scenario, this paper presents an example of how such technology can be successfully employed to achieve global digital dissemination of knowledge among the general public and that public affected by disabilities that can hinder the learning process, using as a case study the collection of Minoan and Mycenaean costume replicas created by Dr. Bernice Jones, a unique collection, subject of several national and international exhibitions, that has become the primarily visual interpretative tool for the study of Minoan and Mycenaean fashion. In particular, Augmented Reality (AR) and Virtual Reality solutions will be discussed.

2 Case Study: Minoan and Mycenean Dress Replicas

The collection used as case study was created by Dr. Bernice Jones, a trailblazing expert in Aegean art and dress history. As part of her research, she has constructed dozens of replica costumes of the Minoan and Mycenean civilizations, and has displayed them in several important world venues, from the National Archaeological Museum of Athens, the Herakleion Museum in Crete, and the Hellenic Museum in Melbourne (Australia) in 2018 with the most recent exhibition at the Institute of Antiquity at the University of Graz (Austria) in 2022. Jones' work, as exemplified in the opening of her seminal monograph on the Bronze Age Minoan and Mycenean civilizations, "attempts to define and understand the construction of the garments, to seek foreign or indigenous sources for the designs, to chart influences abroad, to resolve issues of dating, and where possible to determine the significance of dress and its identification with roles of women" [10]. The Minoan and Mycenean garments reconstructed by Jones are based on artwork dating from 2000 to 1250 BCE on the islands of Crete, Thera (present-day Santorini), and on the Greek mainland. While there are no extant textile finds dating to this period, an astonishing archaeological record including a variety of figures, vases, and frescoes provided Jones with the bedrock to begin her study, coupled with a close investigation of nearby civilizations such as Egypt and the Near East. Each ensemble consisted of at least two parts: a robe or *heanos*, and a skirt, either a double-axe-shaped kilt, or tiered skirt in the case of the interpretation of the Snake Goddess figure. Additional features could be an apron, bolero jacket, headband, or belt to add additional texture. Each garment was based off of an extant archaeological find or iconographic source.

3 3D Digitization, Processing and Online Dissemination

In the Spring of 2022, members of the Institute for Digital Exploration (IDEx) at the University of South Florida (www.usf.edu/idex) 3D scanned eight costumes of the larger collection of replicas. Each garment was scanned using the Artec Eva structured light scanner and processed in Artec Studio 13 Professional. The costumes were placed according to historical and archaeological knowledge on mannequins which were placed in relevant poses for each garment (Fig. 1). Scans were captured using default settings. Post-processing work was done with Geomagic Wrap 2021.

The Artec Eva was operated at a distance of two to four feet depending on the detail needing to be captured. At this range, the scanner was able to successfully image stitches, lose fibers, sheer fabrics, and fringe. Some fringe and netting details were difficult to process, but the texture wrapping algorithm still managed to provide enough information, and the ability to zoom in on the models to the point of seeing visible weaving structure of the textile is exciting. The visible texture of twill tape used as embellishment rendered perfectly to the point where even an amateur sewist with a basic understanding of materials would be able to recognize it as twill (Fig. 2). Variations in hand-dyed fabrics

Fig. 1. IDEx member using the Artec Eva to 3D scan the Snake Goddess ensemble (left) and the Crocus Gatherer ensemble (right)

were clear and visible, and even gentle creases from garment storage, and gathers of material into belts and under the arm of the mannequin were picked up with ease (Fig. 3).

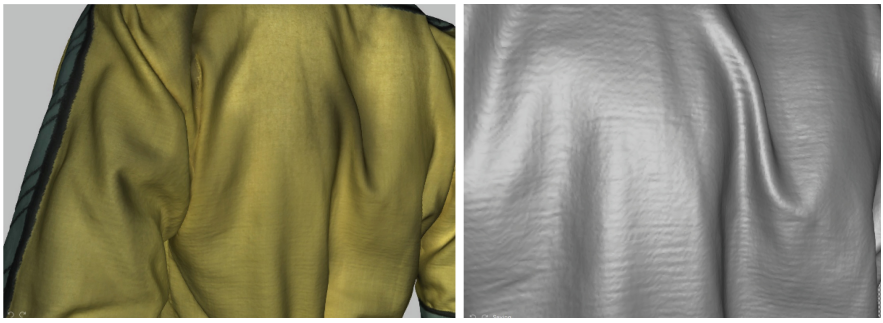

Fig. 2. Screenshots of the Crocus Gatherer ensemble showing the visible textile weaving structure of the in the mesh and texture

Once the processing of the 3D data was completed with Artec Studio 13, the eight 3d models of Minoan and Mycenaean garments were uploaded as a collection on IDEx account on the 3D cultural heritage oriented repository Sketchfab [8] (https://skfb.ly/ovXGq) for global digital dissemination, alongside archaeological metadata and technical paradata. The styled and accurately draped textiles can be found on the mannequins in the digital environment (Fig. 4).

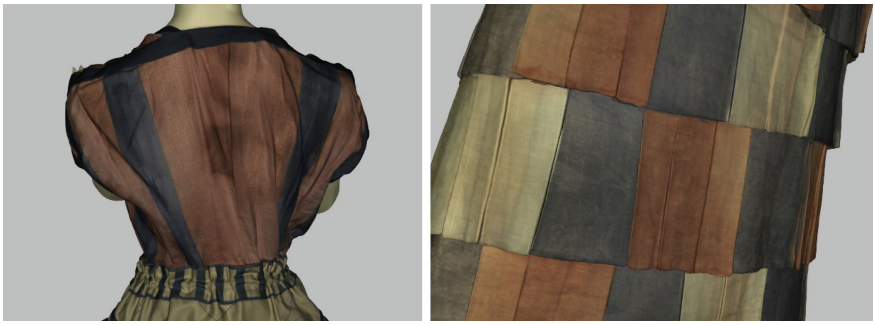

Fig. 3. Variation in the hand-dyed fabrics shown in the texture of the digitized Snake Goddess ensemble's blouse and skirt panels

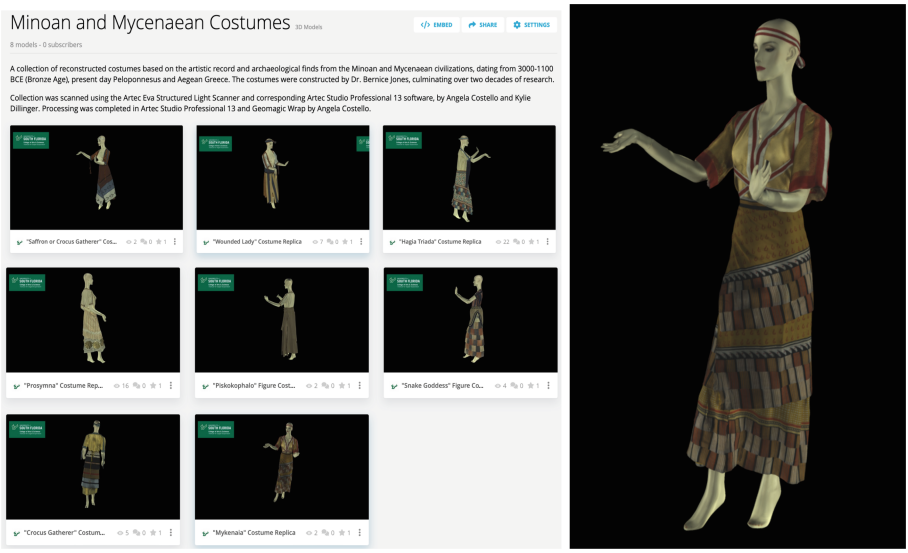

Fig. 4. Collection of the eight 3D scanned garments in the Sketchfab collection (left) and final 3D model of the Mykenaia ensemble (right)

4 Virtual Reality (VR) and Augmented Reality (AR) Applications

The availability of the 3D models of the garments allows for envisioning new communication strategies to reinforce the visual appeal of the exhibition and contributing to a more inclusive experience with less logistical implications. The design of VR and AR applications in a museum environment has in fact demonstrated the important role that those technologies can play with respect to public outreach.

Fig. 5. VR user experience with Oculus Rift (left) and AR visualization interface with Overly app on Android (right)

VR applications are on a growing trajectory in museum environments and for cultural tourism programs [11] thanks to the increased availability of low-cost headsets. Though AR user experiences are still hindered by the technological challenges of the BYOD practice (Bring Your Own Device) [12], their potential in terms of generating engagement across the spectrum of audience demographics is well known [1]. What makes VR and AR strongly appealing are also their effectiveness in enhancing the learning process in users with cognitive disabilities, a segment of the museum audience too often neglected by the mainstream communication strategies [2,9].

In order to provide a digital companion and more inclusive educational tool for the future exhibitions of the collection of Minoan and Mycenaean garments, it was chosen, for the online dissemination, to rely on Sketchfab for its popular VR-ready feature and the size limit for the 3D models that guarantees a smooth interaction with the 3D models even without internet broadband (Fig. 5). These models are accessible using VR via the Oculus Rift and, even using Google Cardboard, upon upload to Sketchfab. This basic tool on Sketchfab allows for the public to experience each costume to scale and to move around freely with the Oculus Rift headset. By providing this functionality, the VR experience provided with the online platform allow the user to more closely examine the garment and more organically interact with the object, producing higher levels of engagement.

With respect to AR, decimated versions in scale 1:1 of the eight digital replicas have been uploaded to the AR platform Overly (https://overlyapp.com) and linked to customized QR code for instant and ubiquitous visualization on mobile devices (Fig. 5). While this initiative requires the user to BYOD, the novelty and ability to place these QR codes within the museum settings allows for increased engagement with the garments that traditional displays do not allow [6]. Overly does require some dissemination in order to house these 3D models, however, seeing as the ability to view the models in AR is limited to whatever device the user has on hand at the time, it is likely that this will be done through a smartphone. Through using the texture files and normal maps, almost no information

is lost and the AR experience is able to be run on most modern smartphones. Even though touch interaction in this AR platform is meditated through a digital screen, the public benefits from this ability to rotate, zoom, and examine the garment.

5 Conclusion

The ability to identify and capture minute details in the texture and mesh of the fabric proves incredibly valuable not only for researcher and conservators but also for the public. In terms of researchers and conservators, the ability to document the weaving structures, stitching, and overall condition of the fabrics provides a wealth of information. In examining weaving structures and stitching, researchers can provide a better hypothesis for how garments were constructed in historical periods, adding to or amending previous scholarship. For conservators, this information allows for a better ability to reconstruct and understand the garment construction and composition to enhance monitoring systems for decay or deterioration of the materials as well as to provide further understanding for reproduction if required. Similarly, the digital twins of fabrics provide an invaluable record for the fabric artifacts which are particularly vulnerable to decay. While the authors recognize that this collection is a series of reproductions based upon scholarship, the study demonstrates the value and ability for structured light scanning in documenting and digitally preserving textiles. These fragility of these materials makes them an ideal candidate for digitization. This record in the digital space produces information and a record of garments to assist in documentation and conservation as well as research and understanding of historic practices in the making of fabrics and clothes.

For the public, the digital models can be used for education, accessibility, and dissemination of knowledge. The history of fashion and dress is quite important in understanding culture and fabrics cannot, and indeed should not, be left out of the digitization movements in cultural heritage. These 3D objects can easily be zoomed in on, rotated, and examined at a much closer angle via public dissemination on websites such as Sketchfab, which also allows models to be embedded into different websites, such as virtual museum galleries. Additionally, the ability to fully rotate and explore the weaving structure of fabrics is engaging, as has been demonstrated with other archaeological materials in museums and educational spaces [7]. This increases accessibility to anybody with internet access, thus minimizing the need for expensive travel, or excessive handling of textile objects which can increase fragility. Additionally, objects that are too fragile for regular display can be digitized in a short period of time, minimizing further damage, as the light patterns from the scanner will only be in contact with the textile for an hour or less. It allows the public to better grasp how historic peoples lived while also allowing them to access the textile artifacts without risk of damaging the materials. Collections that may not have been able to be seen in person for years as a result of their deteriorating state can still be “displayed” virtually. Finally, the VR and AR developments of the virtual

replicas of historical and archaeological garments can immensely contribute to share the knowledge about this peculiar class of artefacts to that disadvantaged public that often is left on the sidelines of the learning process, as this project has tried to point out.

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