The use of 3D virtual technologies for the research, conservation, and dissemination of archeological and historical textiles and costumes

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Abstract

The development of an innovative protocol to study and reconstruct archaeological and historical textiles and clothing using 3D and CAD technologies during the PhD. research about textiles and clothing of the women represented in the wall paintings of Akrotiri and the archeological textile fragments found in situ, shows a break with previous textile research in how it completely changes the scientific approach, the look, and how a textile can be interpreted. The 3D virtual reconstruction of an embroidery decoration, part of a Paracas' mantle belonging to the textile collection of the Musée du Quai Branly-Jacques Chirac, and from a mineralized archeological textile from Kalyvia, demonstrate the importance of virtual 3D reconstructions for not only partly preserved but also deteriorated archeological textile fragments.

Contents

Introduction

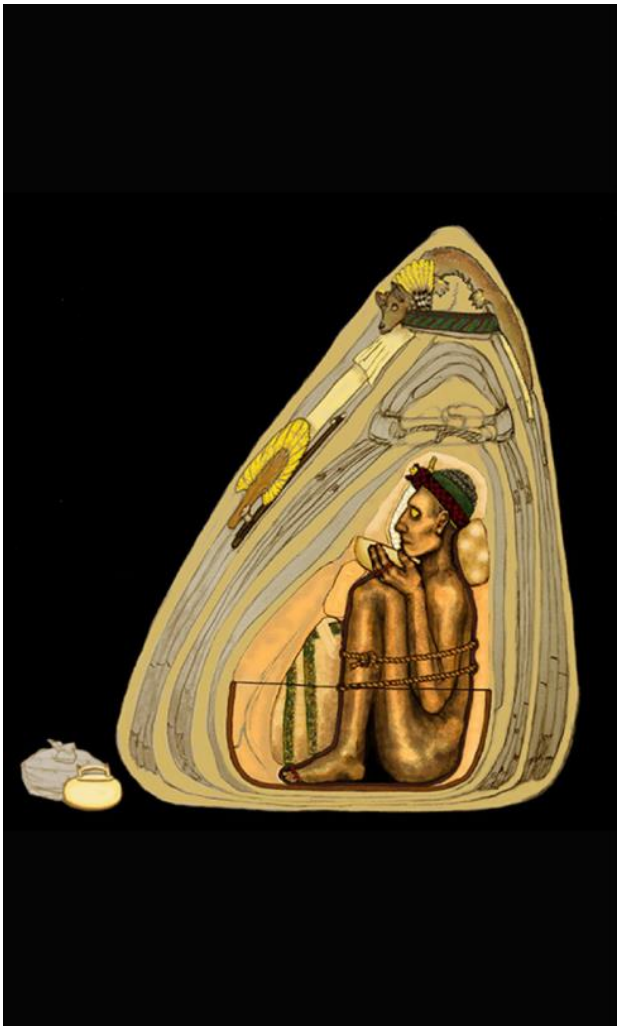
An essential part of preserving the cultural heritage of textiles and costumes is the meticulous research, its dissemination, and the accessibility of information to a broader audience. We can see that new media and 3D technologies can play an increasingly important role in this field. The transition from raw material to a ready-made textile or finished garment requires a whole chain of choices and operations in which the characteristics of the material and techniques and the qualities required for the specific use of the finished textile play an intertwined role. Archaeological and historical remnants of textiles and garments are often not well or only partially preserved, making it challenging to analyze all of the initial characteristics of their production process and visual aspects through microscopic imaging alone. Incorporating 2D and 3D technologies allows virtual recreation of the operational chain from material selection to all the techniques used for producing a finished textile or garment. Visual and behaviorial aspects often not visible in archaeological textiles become visible in their 3D virtual recreations. This new approach is developed and validated in a PhD study about textiles and dresses of the women represented in the wall paintings of Akrotiri and the archeological textile fragments found in situ (Bries 2022). Integration of virtual 3D technologies leads to a more profound contextual

understanding of the studied textile or costume and therefore improves the education, dissemination, and preservation of their cultural heritage.

The next paragraphs will present two types of archeological textile fragments used for analysis and 3D virtual reconstruction: a well-preserved cut-out decoration piece of a Paracas mantle (600BC–150AD) and a mineralized disintegrated textile from a tomb in Kalyvia (500BC–400BC). We would like to thank the conservation department of the Musée du Quai Branly-Jacques Chirac for making the mantle embroidery available for study and 3D scanning, and for their collaboration during the reconstruction process. Special thanks go to Christophe Moulherat from Musée du Quai Branly-Jacques Chirac for the textiles' imaging and microscopic 3D analyses and his continuous support and collaboration in developing the integration of 3D virtual technologies in textile and costume research and museology.

Embroidery mantle Paracas from the collection Musée du Quai Branly Jacques Chirac

Context of embroidery from the Paracas mantle



The 3D virtual reconstruction of an embroidery decoration, part of a Paracas' mantle belonging to the textile collection of the Musée du Quai Branly-Jacques Chirac, presents the different aspects of this new approach. Cut out of a mantle, the remaining decoration only represents a small part of the entire mantle, which raises questions about the missing parts and visualization of the embroidery within a complete mantle. The virtually reconstructed mantle allows a better understanding of the Museum's collection piece and offers the possibility of exhibiting this delicate fragment to a large public without the risk of fragilization. Few museum collections outside Peru possess complete Peruvian mantles, which makes it interesting for the Musée du Quai Branly-Jacques Chirac to have a virtual reconstruction of an entire mantle based on the embroidery.

Fig. 1. Ilustration of mortuary practices, Paracas. Source: *Paracas Archaeology Research Resources*

Paracas mantles are funerary mantles used by the population of the Southern coast of Peru from 600 BC until 150 AD. Clothing had an important role and is described by Anne Paul as "transcending the customary role of protection, emphasizing changes in status within the life cycle and serving as a principal ceremonial good" (Paul 1979, 7). A deceased person was wrapped in multiple layers of woven decorated fabrics and mantles, and buried with offerings (**Fig. 1**). The mantles were meant to cover the mummified person and had a spiritual function, expressed through the fine colorful decorations, which embedded cultural meanings for the Paracas population. The embroidery decoration from the Musée du Quai Branly-Jacques Chirac's collection is an excellent example of such a colorful decoration.

One embroidered decoration part reveals insufficient information for the reconstruction of a complete Paracas mantle. Therefore, the well-conserved mantles in Peruvian Museums and archives are an important resource, which are studied to find missing elements. Pictures from mantles taken in the museums and archives during a textile journey in Peru, and numerous publications on Paracas textiles and cultures (Lavallée 2008; Paul 1979; Paul 1991; Tello and Toribio 1979), made it possible to hypothesize missing elements about the decoration's mantle. Generally, mantles with this type of embroidery have a rectangular shape that can vary between 2.75 m for the large side and 1.3 m for the smaller one (Paul 1979, 19). The large surface in the middle is divided into rectangles or squares, forming a checkerboard pattern. For some of the mantles, this pattern is formed by alternating the decoration pieces on the rectangles/squares and using different colors for the decorated rectangles/squares and the undecorated ones. In all the mantles, the decorations are multicolored, with the colored weave derived from naturally dyed yarns. A unicolor border with similar decorations on the large surface surrounds the central part and is discontinued in the middle of both shorter sides.

3D Research and reconstruction of the Paracas mantle

Throughout the whole reconstruction process of the Paracas mantle, the conductive line is every step in the production process, like creating a physical one. The process starts with capturing 3D images recto-verso from the embroidery (**Fig. 2** and **Fig. 3**), and 3D microscopic views of the details for extracting the technical data of yarns and weaves (**Fig. 4**). The main fabric's yarns and weave characteristics are obtained from the remaining red brick parts in the middle and around the decoration. The red brick unembroidered fabric in the middle of the eyes of the decoration is a perfect study part (**Fig. 4**), as the weave is closed-in and less exposed to extension than the fabric parts around the embroidery. Due to the excellent state of conservation, well-preserved yarns and weave structure delivered reliable and required data for a realistic 3D virtual reconstruction. Red brick yarns from the fabric on which the embroidery is applied are made from alpaca wool, and their thorough analysis results in different yarn types, all used for weft and warp. The yarn diameters range between 0.46 mm and 0.71mm, with diameter variations between 14 percent and 1 percent within the yarns. Differences in diameters and yarns are probably not intentionally created but result from hand spinning techniques. The yarns show all are 2-ply, S twists, and their twists per cm vary from eight to ten. Based on these data, seven types of 3D virtual yarns are created, ensuring the coverage of all the measured characteristics. The fabric structure shows a balanced plain weave with 14 yarns per cm for weft and warp. The weighted average usage of measured yarn diameters is applied in the red brick fabric's 3D virtual warping and weaving. The virtual 3D fabric is subsequently placed on microscopic images of the original fabric to check the accuracy of the yarns and weave.

Fig. 2. Above. 3D scan, recto, embroidery on the Paracas mantle. Musée du Quai Branly-Jacques Chirac
Fig. 3. 3D scan, verso, embroidery on the Paracas mantle. Musée du Quai Branly-Jacques Chirac

Fig.4. 3D microscopic picture from red brick fabric in the middle of embroidered eye decoration.

The missing parts of the mantle need to be virtually created according to the same logic of the operational production chain and based on the sources mentioned above. Observations of complete mantles often show for rectangles in between the decorated parts, the usage of the same material, here alpaca wool, in the same or different color, and a slightly more dense weave. This information has led to creating a hypothetical virtual black fabric with the same types of virtual yarns, a balanced plain weave with a slightly higher density of 17 yarns per cm. The virtual yarns' red brick and black colors are created based on color pixel capturing from red brick yarns around the fabric and the black yarn used for the embroidery.

Once all the materials are created, the 3D virtual reconstruction of the mantle's structure can start as a physical costume. The pattern's drawing is based on characteristics obtained through research of existing mantles and the embroidery's dimensions. The middle part of the mantle is constructed with 41 decorated and 43 black rectangles, assembled in a checkerboard pattern bordered by a red brick band with the figurative decoration, and a small black trim at the outside. The embroidered decorative figure, added recto-verso in five rows, faces the same direction in the middle part, whereas the 20 figures on the red brick band follow a direction going around. The final stage in the process is the virtual sewing of the pattern pieces into a garment.

The created 3D mantle is virtually simulated on an avatar and draped on a flat surface to observe the behavior and drape of the fabric[1] Drape and folds suggest a rather heavy fabric on static pictures and are confirmed by animating the avatar and mantle (**Fig. 5** and **Fig. 6**). Due to this approach, the recto-verso parts become not only visible in one image but also show the embroidery piece in the context of the whole costume, a Paracas mantle.

Fig. 5. Above: Draping from virtual 3D Paracas mantle on avatar.

Fig. 6. Below: Draping from virtual 3D Paracas mantle on a flat surface.

Archeological Textile from Kalyvia, Greece

Context of archeological textile from Kalyvia

What is possible for well-preserved pieces is also achievable for fragmentary, deteriorated archeological textiles like those discovered in mainland Greece. Most of them are associated with metal and ceramics in burial circumstances, and rarely have conserved color pigments or decorative details. The severely deteriorated condition makes them extremely fragile for handling or for exhibition to the public, and the disintegration hinders imagining their initial looks and characteristics like finesse and drape. Fortunately, it is possible to virtually restore their initial characteristics and appearances from mineralized, frozen, or carbonized archeological fragments. It must be emphasized that 3D virtual reconstructions of deteriorated textile fragments are based on dimensions and features from degraded material, sometimes over thousands of years. The degree of disintegration that

[1] As the recreation of an avatar with typical features from the Paracas population is not included in this project, the avatar is deleted. It gives the possibility to see the interior of the draped mantle.

changed the initial characteristics is unknown, so the dimensions and reconstructions should be considered approximative to the original fabrics.

3D research and reconstruction: archeological textile from Kalyvia

In 1999, archeologists on the Kalyvia site discovered about 20 mineralized fragments between 2 cm and 8 cm in size, which belonged to a textile that initially covered the lid and sides from a ceramic *dinos* vase in a marble cist (Moulherat and Spantidaki 2014, 163; Spantidaki 2016, 110). In 2002, the first study of the fragments by Moulherat showed superimposed layers, indicating the folding of the fabric. He counted up to 40 layers for a 2 cm thickness of the fragment, suggesting the finesse of the textile (Moulherat and Spantidaki 2014, 163). Progression in microscopic 3D imaging allowed Moulherat to perform a new study of the fragments in Greece during 2018, which delivered more precise and detailed technical information about the material, diameter, ply, twist direction, and weave structure (**Fig. 7**). Therefore, only the most recently obtained data from the archeological Kalyvia textile are used for the virtual 3D reconstruction as they are much more accurate than those previously published (Moulherat and Spantidaki 2014, 163-66). Additional features, like twists per cm, TEX, weave density variations, cover factor, and fabric weight—not previously studied but important for a profound understanding and necessary for reconstructing yarns and weaves—are obtained by additional analyses of enlarged microscopic 3D images in CAD programs.

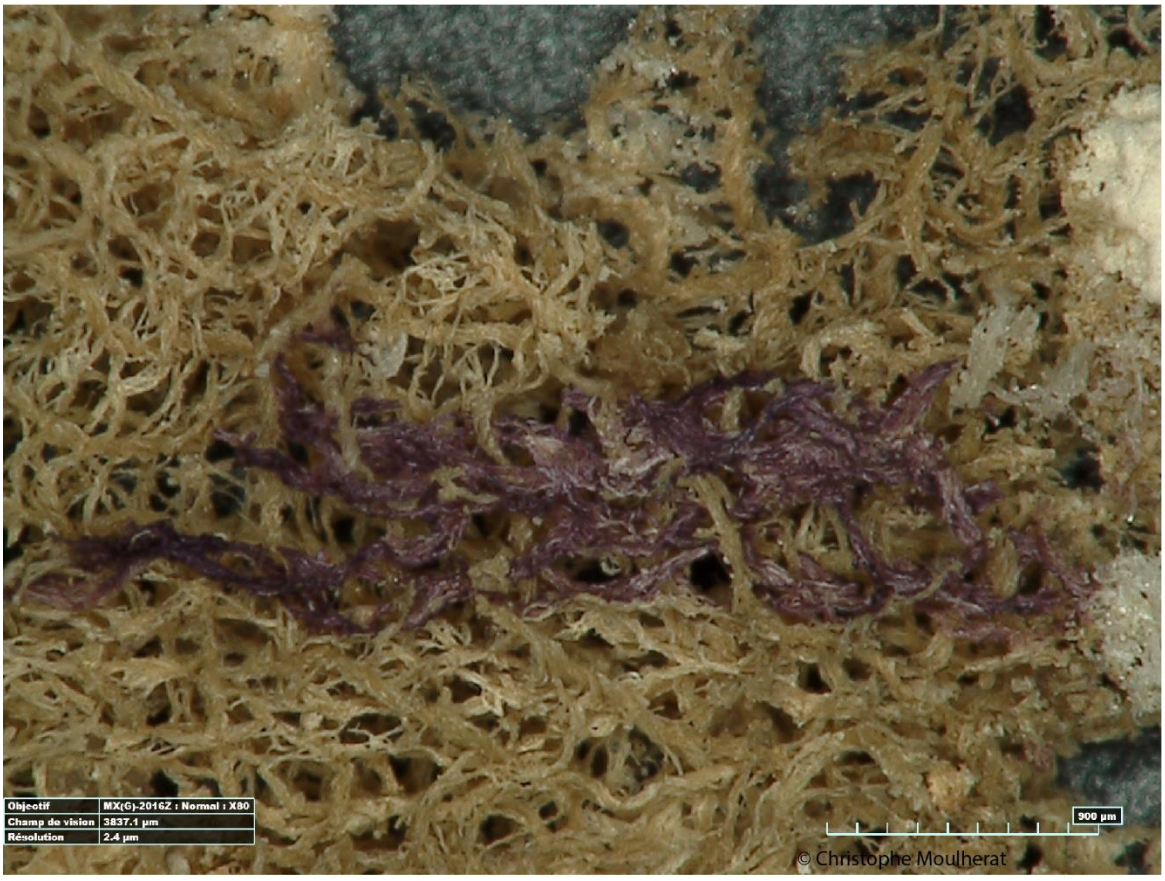


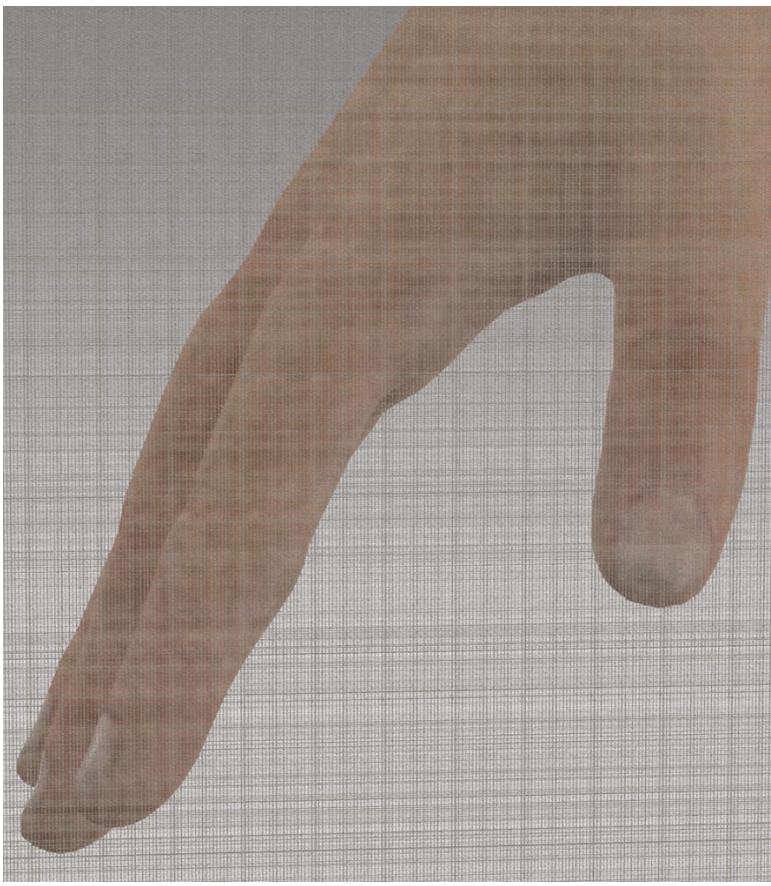
Fig. 7. 3D microscopic image of the textile from Kalyvia.

The Kalyvia textile's weave and warp yarns material is linen, and all are constructed of 1-ply with a Z twist. Other yarn characteristics differ substantially for warp and weft. Warp yarns have an average diameter of 0.106 mm with a variation of 38 percent, five twists per cm, and a TEX of 8.2, whereas weft yarns show a smaller average diameter of 0.055 mm with a variation of 37 percent, hardly twisted, and a TEX of 2.2. At the initial weft border, seven purple yarns, with the dye substances identified as probably *Murex brandaris* (Moulherat and Spantidaki 2014, 164), are used with the same characteristics as the other weft yarns. The warp and main weft yarns are kept in a natural linen color, as no specific dye pigments are detectable on these archeological yarns.

The fabric's structure is identified as plain weave with an average warp density of 25 yarns per cm without a noticeable density variation. However, the weft shows an average density of 80 yarns per cm with a variation of 25 percent. It is impossible to determine if the high variation in weft density was utilized as a pattern or purely coincidentally because of the fragmentary state and folded position of the Kalyvia textile. Therefore a random density is applied for the 3D virtual weave structure, resulting in a textile weight of 40gr/m2 and a transparency factor of 42.66 percent. Seemingly a dense weft with extremely fine handspun yarns indicates the highly technical expertise of the people involved in the fabrication process of the Kalyvia textile.

Because of the state of preservation, it is impossible to determine the exact dimensions or the specific form of the Kalyvia textile. Therefore a rectangle pattern is created for the 3D virtual Kalyvia textile and virtual draping and rendering reveal the weight, flexibility, and transparency (**Fig. 8** and **Fig. 9**). Interestingly the seven purple-dyed weft yarns are hardly noticeable in the draped fabric, raising questions about their functionality. Certainly, their decorative purpose was very limited, suggesting a meaningful, coded function.

Fig. 8. Close up 3D virtual reconstruction of the textile from Kalyvia.



The virtual 3D reconstruction of the archeological, mineralized, and therefore extremely fragile Kalyvia textile shows how these technologies are important for a more extensive understanding, revealing characteristics that are not observable in the archeological pieces.

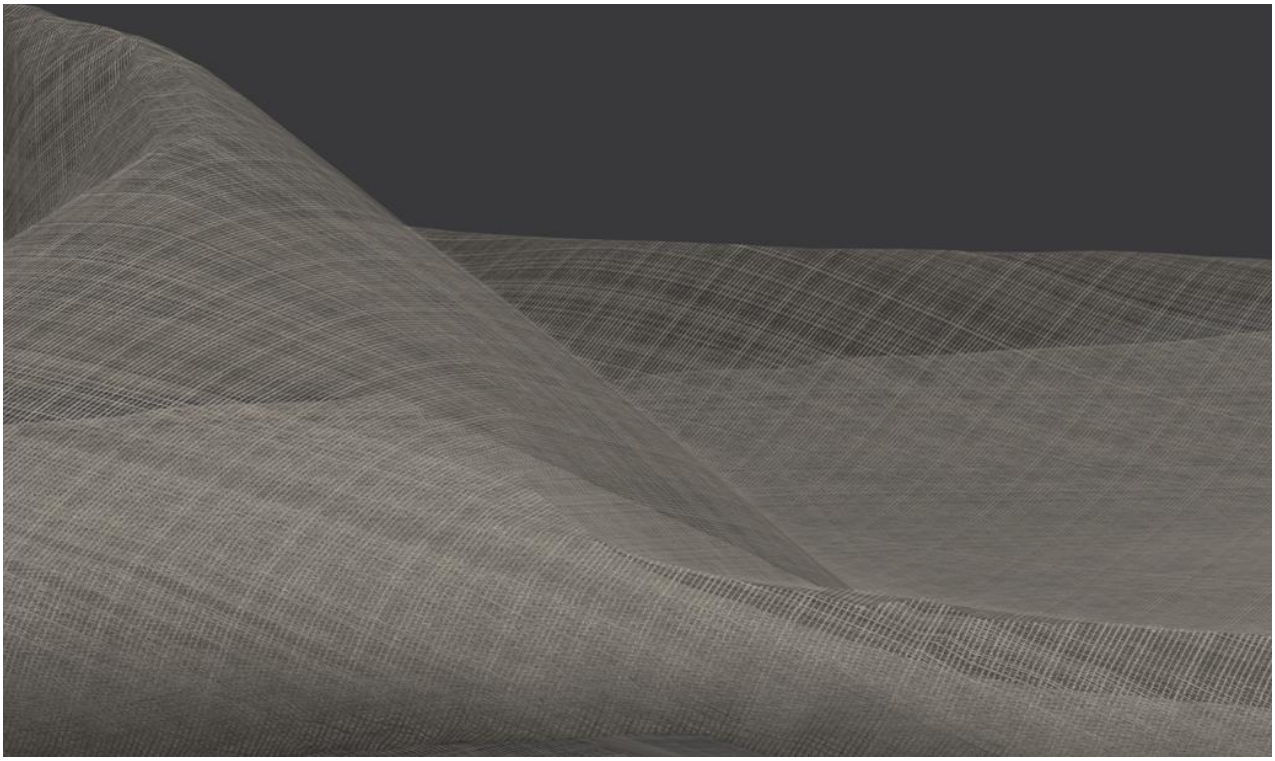


Fig. 9. 3D virtual reconstruction and draping of the textile from Kalyvia.

Conclusion

New technologies related to 3D imaging have focused mainly on studying architectural buildings, monuments, sculptures, and ceramics. Textiles and costumes have hardly been used in these studies and are mainly focused on microscopic analyses and studies of textile tools. Therefore, the integration of virtual 3D technologies for studying archeological fabric fragments and garments represented on Akrotirian frescoes in the PhD dissertation of Bries offers new possibilities for the analysis, education, and dissemination to a large public of fragile textile and costume heritage (Bries 2022). The research entails developing an innovative protocol for virtual 3D reconstruction of textiles, whatever their condition—that is to say, from well preserved to a high degree in alternation, but also iconographic representations. The protocol shows a break with previous textile research in how it completely changes the scientific approach, the look, and how a textile can be interpreted due to the introduction of new parameters in the 3D virtual reconstructions.

Archeological and historical textiles and costumes require careful handling and are sensitive to environmental aggressions like insects and light. Consequently, they are often difficult to study and impossible to present to the public because of their extreme fragility. These 3D technologies allow us to approach them without risk, to virtually restore them, and to present them in a high-quality digital form to the public. Researchers and the public will be able to observe them closely, place them in historical context, and soon have the sensation of touching pieces that normally are inaccessible because of their fragility or their geographically remote

presence. These 3D virtual textiles and costumes can circulate freely in the context of worldwide exhibitions, without any restrictions for damage or conservation issues,.

Based on a fragile decoration piece, the above-presented reconstruction of an entire Paracas mantle illustrates the possibilities for integrating 3D virtual technologies in the museology of textiles and costumes. There is a different approach for virtual 3D reconstructions of generally known and relatively well conserved pieces, such as Paracas mantles, and altered preserved archeological fragments, for which nobody knows their initial visual aspects. Nevertheless, the virtual 3D reconstructions of disintegrated archeological textiles reveal features from the original fabrics without pretending to have the status of exact copies. Thanks to this digital approach, the study of visual and behavioral aspects of archeological fabrics, previously impossible, becomes a reality. Equally, their virtual reconstructions open up comparisons with iconographic representations of fabrics and garments and allow us to place them in a broader historical and anthropological context. Collectively, these technologies offer a new perspective in the study, education, and dissemination of archeological textiles.

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