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To See the Unseen – Computer Graphics in Visualisation and Reconstruction of Archaeological and Historical Textiles

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1. Introduction

Computer graphics is widely applied in many areas of science, engineering, education, advertising and entertainment. More and more often computer art can be seen in museums, both as individual works of art and as a supplement to museum exhibitions. The latter includes animation often used as a background enriching an exhibition or being simply an element of scenography. However, sometimes it can have a more important function. Specialized software and interactive devices permitting users to interact with a virtual world by manipulating objects can play an educational role. Multimedia presentations are sometimes used in interactive museum kiosks with touch-sensitive screens or on museum websites, permitting the looking of objects, some detail of their structure, rotating them or even looking inside. They can show a method of manufacturing, or natural and historical context.

Virtual artefacts we can see in museums or on the Internet are, in most cases, virtual copies or imitations of real historical objects. In most cases they are based on 3D scanning. However, these methods do not give satisfactory results, even when applied in the case of ceramic or metal sculptures, which are much easier to imitate than textiles. Despite the progress in 3D graphics, 360° photography still gives much better effects (Johansen, 2010).

The purpose of the research presented in this chapter is different. Methods of computer graphics are applied not to imitate or copy anything but to show what is hidden, what we can't see because of indirect contact with the object in the museum or because the object due to ageing is destroyed or sometimes even doesn't exist in any form but a short description (Andersson & Cybulska).

Computer graphics presented in the chapter were made with the use of *3ds max* software offering variety of tools, but also "maxscript" programming language. It allows the development of its own procedures that can be applied in the case of textiles.

2. Computer graphics in modelling textiles

2.1 Appearance of textiles

The appearance of textiles is a very complex phenomenon. It is the combined effect of many different factors: raw material, yarn and fabric structure, finishing and many other

parameters resulting in a different properties as width, areal weight, stiffness, and so on. These parameters determine some other factors, as fabric texture or drapeability. On the other hand, the appearance of textiles is determined by light reflection and refraction, translucency, colour, etc. All these parameters should be taken into account in modelling and simulation of the textile object. (Cybulska & Florczak, 2006)

Fibres used in historical and contemporary textiles can be characterised by different cross-section and surface properties. For instance, cotton fibres have a form of twisted ribbon with a bean-like cross-section. A triangular cross-section of silk results in semigloss in contrast to circular polyester filament giving the thread or woven fabric a full gloss. Modern fibres are designed to have some particular properties, such as a good heat insulation or capilarity, which can be achieved mainly due to geometrical properties of the cross-section.

Fibres can be grouped together to create a coherent, continuous object called yarn or thread by wrapping, twisting or nodding them, according to yarn technology. Two or a higher number of yarns can be also twisted together creating plied structure. The appearance of yarn depends on the kind of fibres used: their length, diameter, luster and colour. Yarns made from filaments are smooth and glossy while these made from staple fibres are lustreless and hairy.

Woven fabrics are created from two sets of threads – the warp and the weft, which overlap and interlace with one another in a variety of ways called weave. The weave can be presented in the form of a diagram on squared paper, where squares filled with black mean the warp overlaps the weft, while white squares denote the overlapping weft. In mathematical terms it is simply a binary matrix which allows the controll of the loom mechanisms during the weaving.

The weave together with warp and weft structural parameters, colour and their spacing in the fabric result in the fabric patterning and appearance.

2.2 Modelling the fibres and yarns

The basic element of modelling is a grid object. Its shape depends on the geometric properties of the modelled element. In the case of fibre or yarn we can assume it is a kind of cylinder with different types of cross-section. Then the object can be modified using a variety of tools, which can change the structure according to specified parameters of the object or technology used, for instance by twisting, wrapping or bending the elements or by adding the noise to reflect the object's unevenness. To create the effect of reality we need to use some tools to determine the texture of the object - smoothness, hairiness, relief, translucency, glossiness, reflection and refraction of light.

Using software tools one can create models of fibre characterised by a different cross-section, diameter and length. We can start from a cylinder of an assumed cross-section. All fibre parameters can be further modified by extruding or twisting, according to the material characteristics. Procedures of the material editor can be used to determine some surface properties, like colour, roughness or smoothness, translucency, etc. This approach is correct if we want to visualise the fibre for educational purposes. For modelling the yarn we need to use much simpler models of fibres.

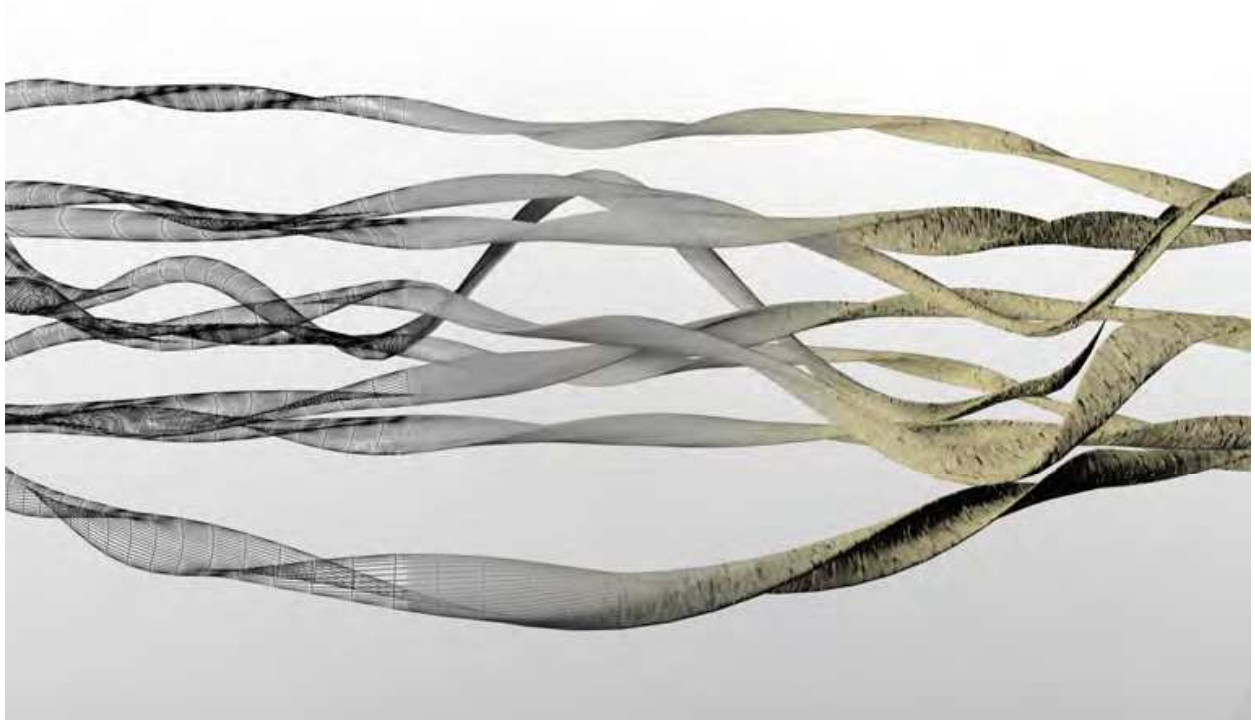


Fig. 1. Modelling the cotton fibre.

One can use two different methods of yarn modelling. The first one consists in giving the linear object the texture determined by the structural properties of the yarn. The presence of fibres is reflected by concavities and convexities on the cylindrical yarn surface. The effect can be achieved by some procedures of material editor. This method can be used in the visualisation of multifilaments.

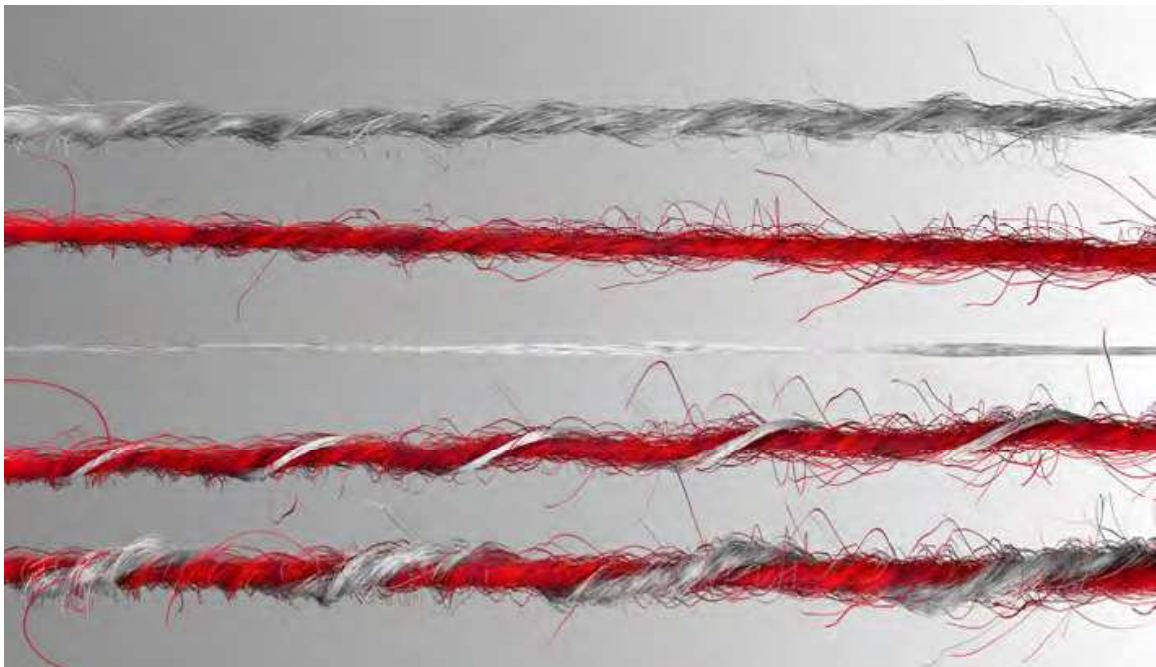


Fig. 2. Modelling the yarn. From the top: staple yarns, multifilament, plied yarns

In the case of staple yarn the method is not sufficient to create a realistic model. Thus the second method consists in forming the yarn from previously created 3D models of fibres, by distributing them along the yarn axis. The method allows the setting of some predetermined features, such as yarn unevenness or yarn hairiness for staple yarn (Cybulska & Florczak, 2006).

2.2 Modelling the woven fabric

Simulation of the woven fabric proceeds in two stages. The first one consists in forming the fabric from previously modelled linear elements. One can use both the exact simulation of yarn or yarn modelled by a simplified method. In the first case one can get a magnified image of fabric with clearly seen fibres. It is also possible to use the elements plied from two or more linear elements such as a warp or weft.

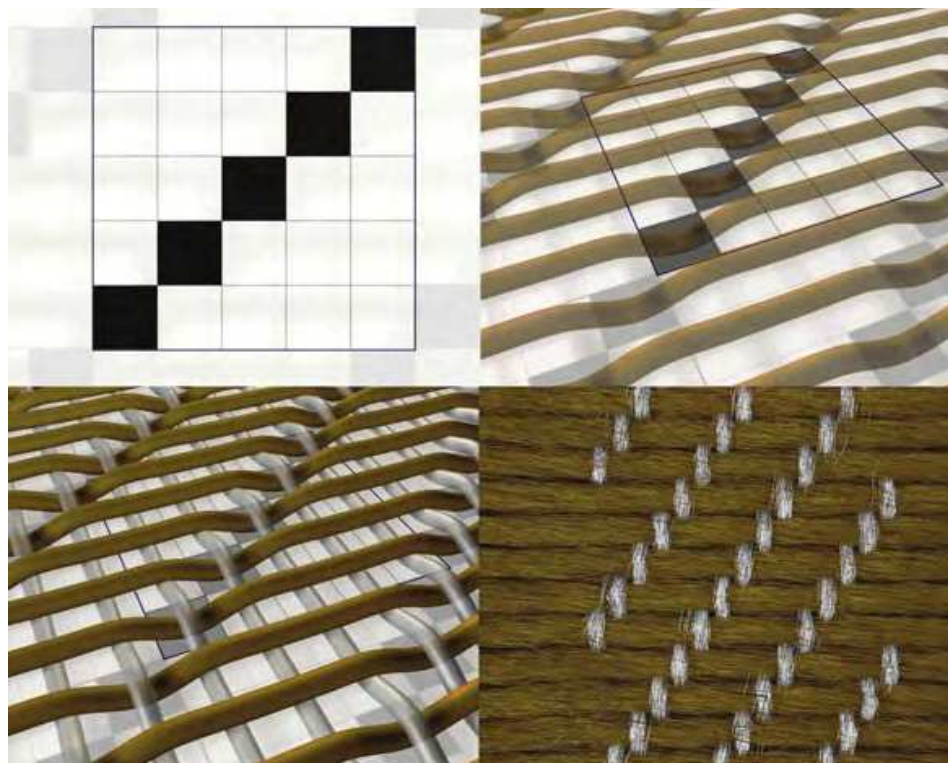


Fig. 2. Modelling the woven fabric

The elements are interlaced accordingly to the previously chosen weave presented in Fig.1 (top left). The number of rows and columns in the diagram correspond to the number of weft and warp threads. White warp overlap green weft if the appropriate square in the diagram is filled with black, thus it is very easy to develop a procedure for creating simplified models of woven fabric on the basis of binary matrix. The relative positioning of threads is determined by the diameter and spacing of warp and weft in the fabric we want to visualise.

The next stage consists in simplifying the 3D model of fabric by converting it to the flat object with texture depending on the properties of the raw material one wants to use. The calculation window allows one to determine some physical properties of fabric, such as areal weight.

The last stage of modelling the textile object of interest consists in placing the previously designed and visualised fabric on the surface of different kinds of 3D objects (Cybulska & Florczak, 2006).

3. Virtual reconstruction of textiles

3.1 Methodology

Textiles represent a variety of structures, materials and technologies, sometimes complex and often distorted, which makes them especially difficult to analyse by archaeologists or historians of art. In many cases documentation of textile collections is incomplete, using traditional, manual methods and thus not precise. It doesn't give us any idea of how the object originally looked. It is especially important in the case of archaeological textiles which are often fragmentary preserved, colourless, and thus hard to appreciate and understand by the unprepared visitor. Reconstruction of these textiles on the loom can be done. However, this approach is not always possible and sometimes not even reasonable. Reconstructed this way object needs proper storage, exhibiting and conservation, and is rather costly¹. In 2003 at the Institute of Architecture of Textiles, Technical University of Lodz, the idea arose to apply quite new tools in reconstructing textiles, using the method of computer graphics.

Reconstruction of textiles on the basis of excavated residues or fragments from museum collections, both real on the loom and virtual using 3D graphics methods, needs knowledge of historical manufacturing methods and the data concerning the reconstructed object. It requires complex analysis, including iconography, historical context, dyes applied, structure and the technology of threads, woven fabric and other components.

Among many available methods of modern analysis of textiles one can mention optical microscopy and image analysis for determination of structure; scanning electron microscopy (SEM), infrared spectroscopy (IR Spectroscopy) and atomic absorption or atomic emission spectroscopy (AAS/AES) for determination of the materials; high performance liquid chromatography (HPLC) for dyes analysis (Cybulska et al., 2008).

The whole procedure of reconstruction includes the following stages:

1. Documentation of the object including photographic documentation of the whole object and its components, sampling the material for further physical and chemical analysis, acquisition of microscopic images of the material.
2. Determination of the raw material and dyes.
3. Structural analysis including the processing of registered images, determination of structural parameters of fibres, yarns and fabric and determination of the object technology, structure and ornaments.
4. Virtual reconstruction of all components of the object, i.e. fibres, yarns and woven structures and reconstruction of the whole object.

3.2 Reconstruction using 3D graphics

The first stage of virtual reconstruction of the textile object is a careful analysis of the structure. In Fig.3. we can see a fragment from the Roman period made on weighted and tablet looms. According to archaeological experience it is a fragment of a parade cloak.

¹ Attempts to reconstructing textiles have been undertaken since a long time. Among the most interesting are the works of dr Karl Schlabow – founder and director of Textilmuseum Neumünster. On reconstructed warp-weighted loom he wove two beautiful Prachtmantels - replicas of those found in offering deposits in Thorsberg and Vehnemoor bogs. However this kind of reconstruction is difficult and time-consuming (it took several months) and, first of all, it requires skills in weaving on an ancient loom. (Schlabow 1976).



Fig. 3. Fragment of parade cloak from Odry, Poland

We need to visualise all identified structures using described in section 2 methods, taking into account all the results of structural analysis of yarns and woven fabrics. In Fig.4 we can see the main fabric of the cloak and two kinds of border made on tablets.

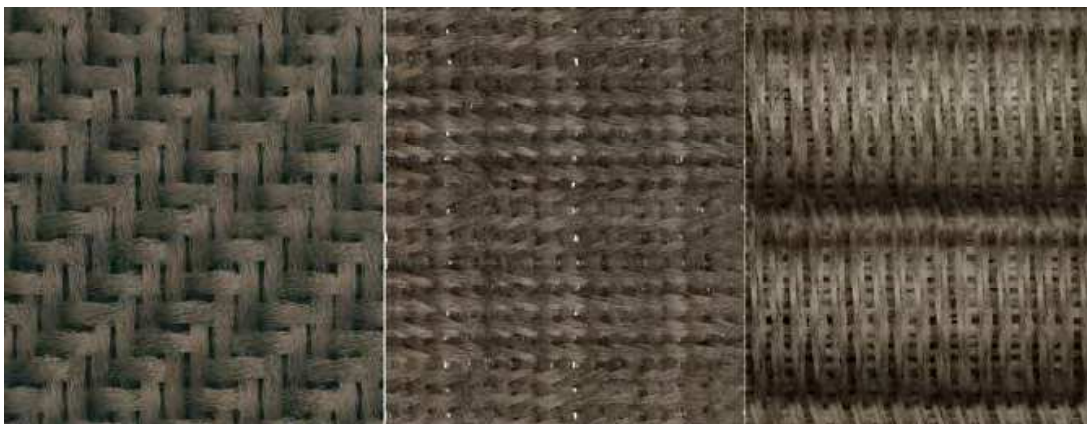


Fig. 4. Visualisation of different types of woven structures

We need to know how many tablets were used, what was their shape and what way they were rotated. In the case of patterned object we additionally need to determine the pattern and the colour of threads. In the case of the pattern presented in Fig.5. it is necessary to determine what is the order and the number of warp and weft threads in each identified colour.

At the end we need to determine the shape and size of the original object. Sometimes it is possible to determine this on the basis of analysis of preserved fragments, however in most cases we use similar archaeological finds which are better preserved or analogical objects from museum collections.

3.3 Reconstruction using raster graphics

In museum collections there are numerous textiles which are partly destroyed. For many reasons conservation of these textiles rarely consists in reconstructing their original appearance. There is no way to bring back the original intensity of faded colours. Sometimes it can be hazardous to apply new materials on fragile, weakened silks or linens. However,

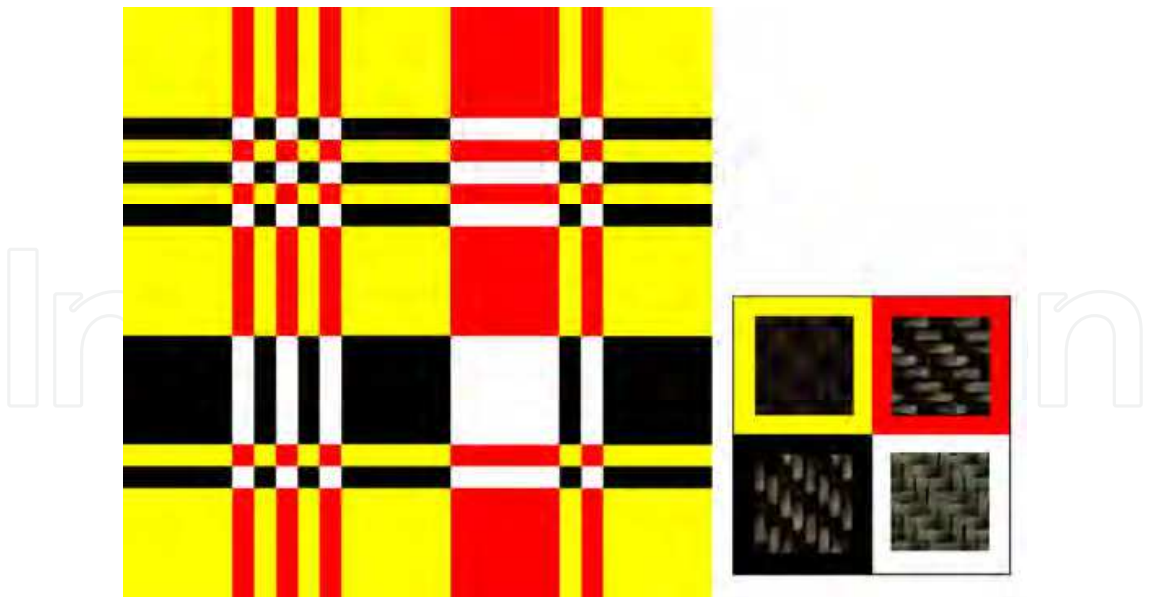


Fig. 5. Visualisation of the pattern



Fig. 6. Fragment of wall hanging (embroidery and appliqué work). Top from the left: before conservation, after conservation, after virtual conservation. Bottom from left: wall hanging before and after virtual conservation

we can make an attempt to reconstruct their appearance using computer graphics. This process we call “virtual conservation” permitting not only the correction of faded colours, but also the “replacement” of missing threads or larger fragments of fabric or embroidery, or to “remove” the results of improper conservation of the object.

On the basis of materials we need, we can organise the collection of patterns reflecting different kinds of threads and woven fabrics and apply them using brushes, stamps and many other tools. Although it looks quite easy, this approach also needs careful analysis of the object to determine all materials which were originally used and the whole decoration we need to restore.

4. Exemplary applications of computer graphics in the visualisation and reconstruction of historical and archaeological textiles

4.1 Woven fabric from the “princess” grave, Leśno, Poland

In the grave dated from the 2nd century and called the “princess” grave due to the rich equipment and a young woman buried there, the numerous fragments of wool fabric were found. (Kanwiszerowa & Walenta 1985). Most of them were probably residues of clothing, because they were found just near the skeleton. However, several fragments were found in, under and on the edges of a bronze pot. The arrangement gave the impression that the pot was wrapped with the fabric and deposited as burial goods for the women for her journey to the other world. (Maik 2005, 98-112).

The fabric was initially classified as an open work. However, microscopic and chemical analysis showed the residues of putrefied fibres (probably linen) and traces of crimp on the survived wool threads. It caused one to assume the fabric was originally made from wool and linen. The fabric was made with 2/2 twill weave. Using image analysis it was possible to determine the diameter, crimp and spacing of the yarn, the number of existing woollen yarns and previously existing linen ones. Analysis of dyes indicated the presence of indigotin, giving the blue colour of wool (Walton, 1993). The flax, as a cellulose fibre, was not yet dyed in that time, so it was assumed the linen threads were in natural colour. The reconstruction of fabric can be seen in Fig. 8 (Cybulska et al., 2009).

4.2 Parade cloak from Gronowo, Poland

In the male grave in Gronowo, dated from the 4th century, numerous fragments of two fabrics and fringes were found next to the man’s feet. They were all compacted into one ball with the metal spur inside. After cleaning the find it occurred the fabrics are residues of two *prachtmantels* with tablet woven borders and fringes. One of the cloaks was monochrome, the second was polychrome chequered from dark and light brown threads (Fig. 5). They were probably used to wrap the dead men body (Maik, 1979). The analysis of dyes was made for polychrome fabric only. Tannin was found in the dark threads indicating brown colour. As there was no dye found in the light threads, they were probably in natural wool colour (Walton, 1993). Further analysis allowed to determine the object structure. The main fabric was made on a weighted loom using twill weave 2/2 S. Borders were made on 30 tablets, with density 13 tablets per 1 cm, all from the light thread used as warp. Fringes were in different colours, depending on their position in relation to the main fabric.



Fig. 7. Fragment of textile found inside the bronze pot in Lešno

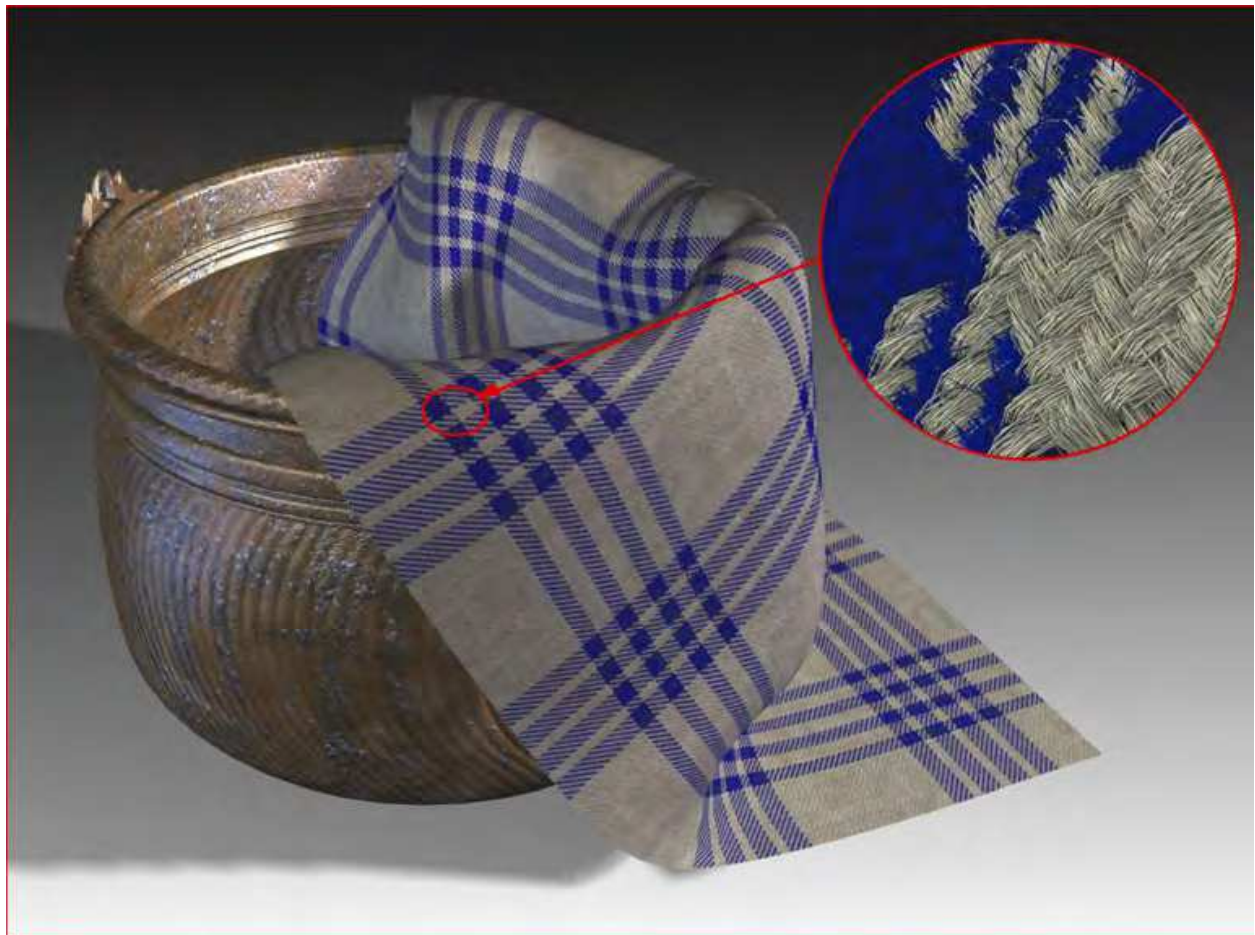


Fig. 8. Reconstruction of the woven fabric from the “princess” grave from Lesno

In the next stage all elements were virtually reconstructed, including the main fabric, borders, corners and fringes. All these elements were used to reconstruct the whole cloak (Fig. 9) (Cybulska et al., 2009).

4.3 Orphrey from Tum

Fragments of embroidery found during the excavation in 1955 in the grave dated from the 16th century in the collegiate church in Tum, Poland, were placed under the hips and thighs of the buried body. The position of the textile, the fact that it was clergyman buried in the grave and the analysis of the fragments, makes one assume that the object is a fragment of a chasuble. The whole object includes a number of fragments of figural embroidery, which was the orphrey decorating the back of the chasuble. We can not be sure that the fragments include all the material that survived to our time. In the 1950's of the 20th century textiles were not treated as carefully as today. The object was moved from one place to another approximately sixty years after excavation. Thus some fragments could have been overlooked or become lost.



Fig. 9. Textile fragments and reconstruction (at the bottom and on right) of the parade cloak from Gronowo

In its current state it includes a number of separated pieces of embroidery. Five fragments represent the heads in different positions: one head with nimbus and one with nimbus and curled hair, two heads with no nimbus in half-profile, both with curled hair and one head with crown. The other fragments represent the second crown, regular fragment of embroidery resembling the cloth, the nimbus attached to the long fragment of embroidery, which was probably the background for the figures and the long piece of embroidery in a form of a meander. The best preserved fragments are the beautifully elaborated figure with raised hands, one foot and no head and the coat of arms of three gold fish in a red field.

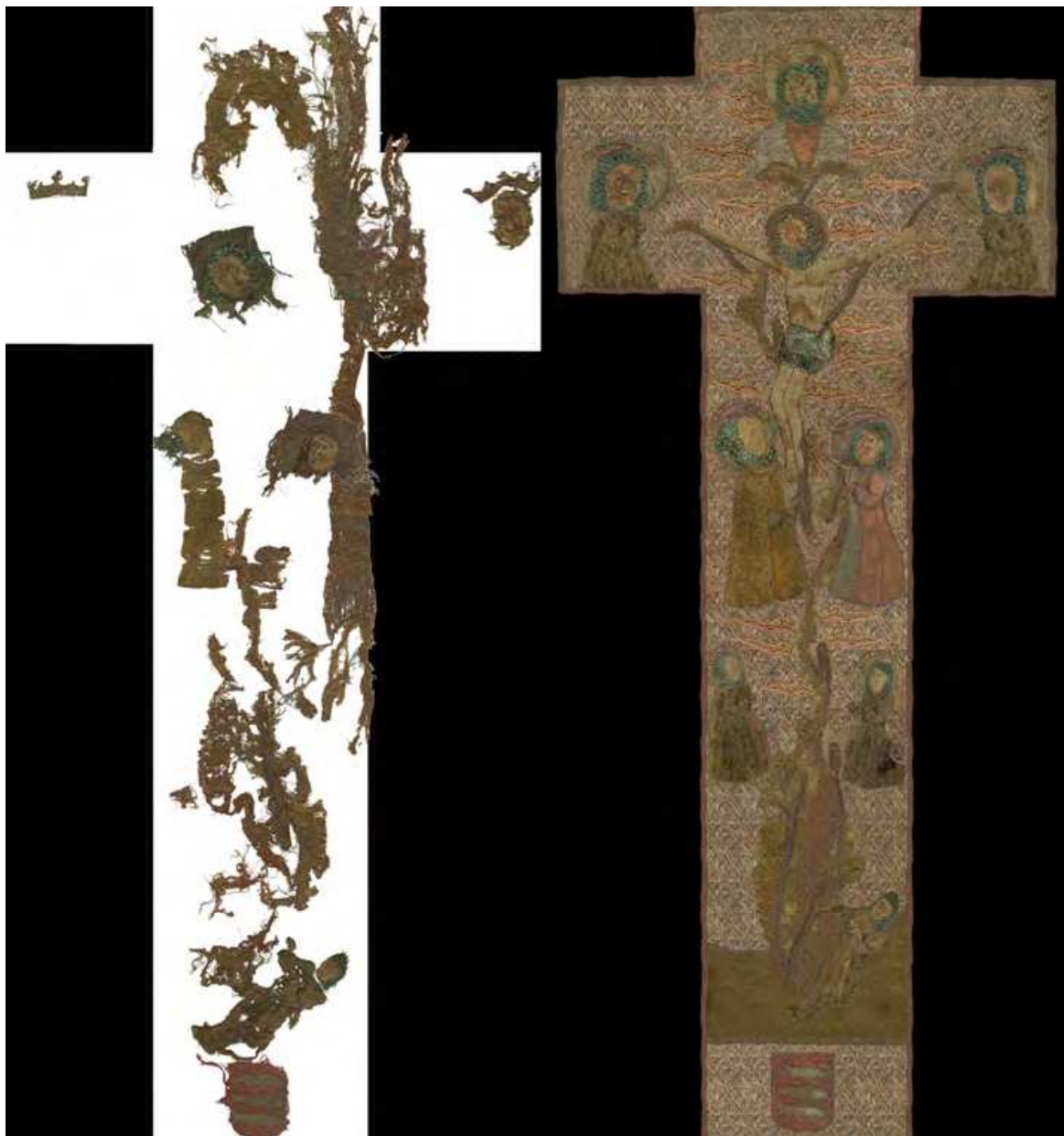


Fig. 10. Orphrey from the Tum collegiate church. On the left – the arrangement of surviving fragments, on the right – reconstruction of the orphrey by means of computer graphics

On the basis of analogical historical objects and analysis of the surviving fragments we made an attempt to reconstructing the orphrey. At the beginning we had to carefully analyse all fragments and their hypothetical positioning in the orphrey. We prepared the background in the form of the back of the chasuble with the orphrey in the shape of cross approximately 20 cm wide. We carefully placed all fragments on the drawn orphrey. Analysis of the surviving fragments allowed to associate them with a presentation of the tree of Jesse and the scene of the Crucifixion.

In Fig. 10 and 11 one can see the embroidery as it would look if the whole object had survived to our time. In the virtual reconstruction we used only images of original elements of the preserved fragments (Cybulska et al., 2012).

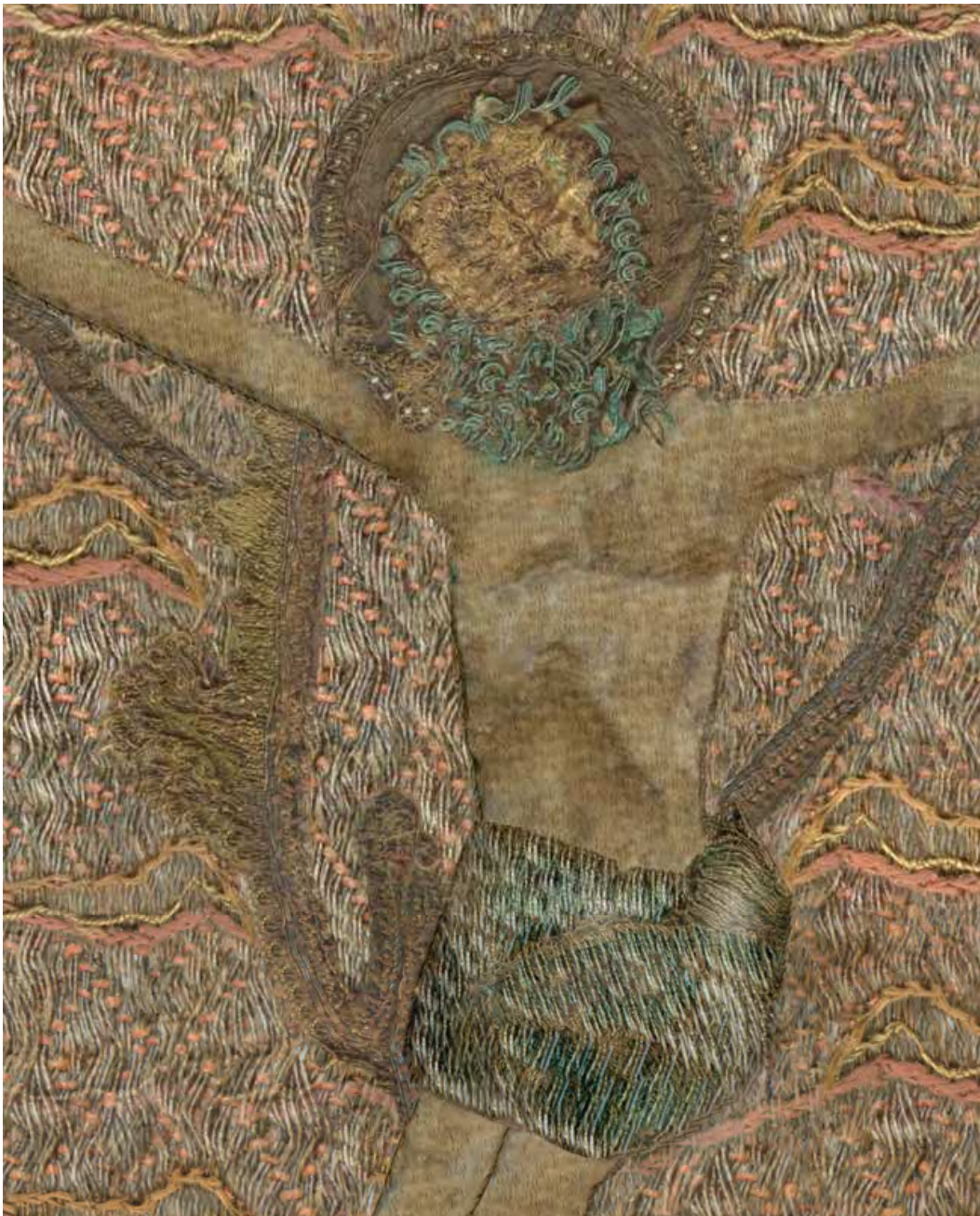


Fig. 11. Orphrey from the Tum collegiate church. Detail of the reconstruction of orphrey

4.4 Visualisation of the complex structures

The 18th century chasuble from the Lowicz cathedral represents a complex textile structure with two independent layers. The background is from pink silk taffeta. On the top is placed the hand-made silver net. The net was made on the basis of the four-cross silk leno fabric. Metal thread consists of a silver strip wrapped around a linen core. Silver threads (two in one course) are put onto the leno and sewn together with a white silk thread. The successive stages of the fabric formation are visualized and presented in Fig.11. In the last stage the net is laid on the pink taffeta background. This kind of visualisation can be a part of object documentation and support its conservation.

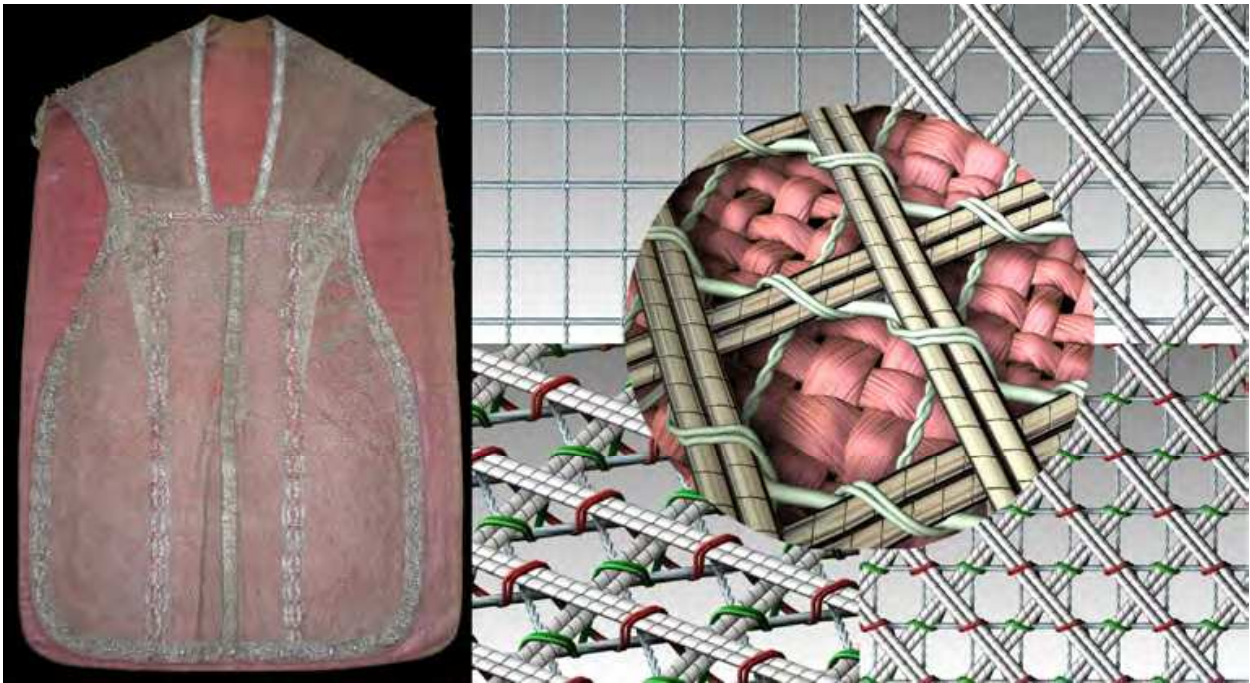


Fig. 12. Chasuble form the pink taffeta decorated with silver net. Visualization of the structure.

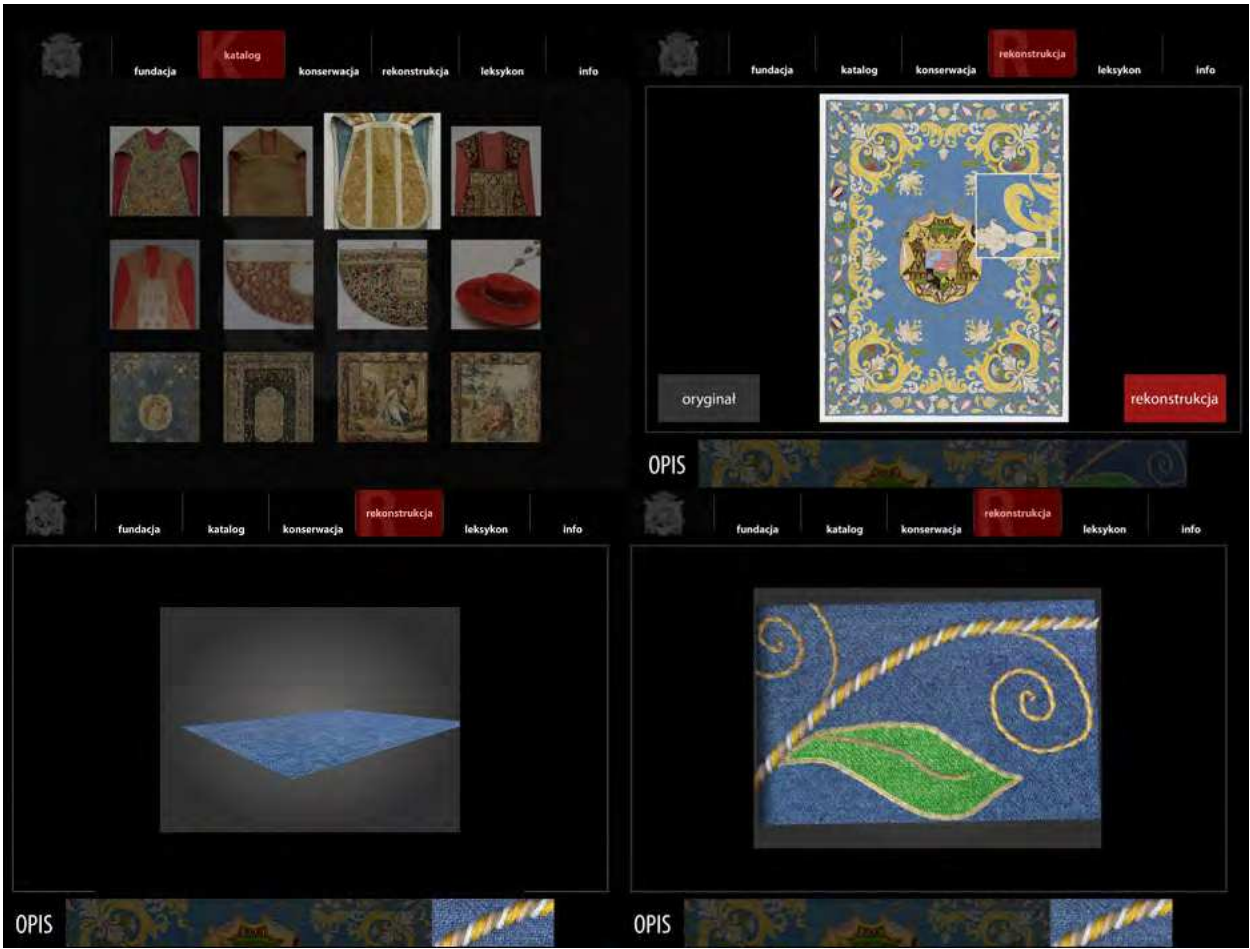


Fig. 13. Exemplary screens from kiosk presentation for the exhibition “Feast of Baroque”

4.5 Multimedia presentation in the museum

People visiting museums often complain about the way objects are exhibited. A long distance from the object, darkness, glass show-cases reflecting external light, not allowing one even to clearly see the objects, not talking about direct contact. The solutions that one uses to preserve works of art do not at the same time really allow one to appreciate them. Thus more and more often exhibitions of works of art are supported by multimedia presentations with easy access to knowledge concerning the objects. Using multimedia we can provide not only the text and images of the objects as they look now. We can also show some details of the structure, present what is hidden, what we can't see in the museum because of indirect contact with the object or because the object due to ageing is has been destroyed. Reconstruction by means of computer graphics can be one of the elements of multimedia presentation, which can offer also a closer look at the details of the object which can't be directly seen. It can present the conservation the object was treated with and the knowledge for visitors who want to know more, in the form of on-line lexicons of technical and artistic terms. In the presentation for the museum kiosk we can use all kinds of digital works: photographs, movies and computer works, as animations, visualisations and reconstructions. Flash presentation made for the exhibition "Feast of Baroque" in Wilanow Royal Palace, included all above mentioned elements.

5. Conclusions

The main advantage of virtual reconstruction is their accessibility not only in the museum, but also on the Internet, both for professionals interested in the subject and society as a whole. Apart from the way they are presented they can clearly show the whole reconstructed object and some details of the structure. The educational role of reconstruction is also very important. When studying any archaeological object in its current state, a chance to know its original structure and appearance is very valuable. Archaeological textiles are very good example – colour and shapeless residuals can get back their form and beauty.

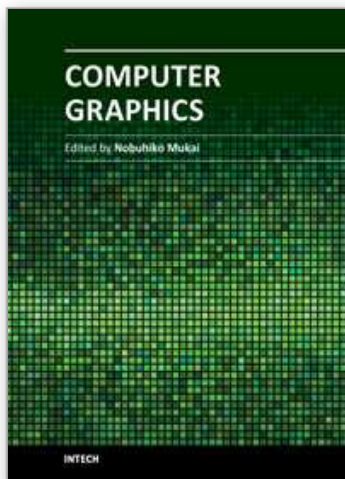
Virtual reconstructions of textiles can also serve as a good and interesting supplement to museum collections. It is well known that as much as we know is as much as we can see and understand and thus more appreciate the merits of the objects we watch. Textiles are very good examples. They are often treated the same way as paintings, however the closer one looks at complicated structures and the variety of techniques and material used in one object the more enchanted even indifferent or sceptical spectators can become.

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Computer graphics is now used in various fields; for industrial, educational, medical and entertainment purposes. The aim of computer graphics is to visualize real objects and imaginary or other abstract items. In order to visualize various things, many technologies are necessary and they are mainly divided into two types in computer graphics: modeling and rendering technologies. This book covers the most advanced technologies for both types. It also includes some visualization techniques and applications for motion blur, virtual agents and historical textiles. This book provides useful insights for researchers in computer graphics.

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