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Book Title	Digital Cultural Heritage	
Series Title		
Chapter Title	3D Models of Ancient Greek Collection of the Perm University History Museum	
Copyright Year	2018	
Copyright HolderName	Springer International Publishing AG, part of Springer Nature	
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Keywords (separated by '-')	3D model - Photogrammetry - Ancient greek collection - Low cost digitization - Access - Usage	



3D Models of Ancient Greek Collection of the Perm University History Museum

Creation and Use

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Abstract. Exhibits of the ancient collection of the Perm University History Museum have a significant historical and cultural value. The purpose of this article is to demonstrate the experience to implement low budget digitization, creation and use of 3D models of the antique collection of the Perm University History Museum. The article describes the technological process of 3D models' creation. It also shows ways how to overcome the limitations of the automatic digitization process (correction of a polygonal mesh, texture, etc.), examines ways to verify the correspondence between the created digital copy of the exhibit and the original, and shows the possibilities of using the created collection of 3D models in scientific research, education and popularization of historical and cultural heritage. The creation of 3D photogrammetric models of exhibits and their publication online improve access to historical and cultural heritage items for their subsequent use. Perspective directions for the secondary use of digital items are scientific study of exhibits, use in educational activities in the training of specialists in the field of Digital History and as illustrative material, as well as solving the problems of historical reconstruction of objects' domestic use and popularization of historical and cultural heritage among various categories of the population.

Keywords: 3D model · Photogrammetry · Ancient greek collection
Low cost digitization · Access · Usage

1 Introduction

Perm State University was founded in 1916 as Perm Department of Saint Petersburg State University. The status of the Imperial University suggested the existence of museums with exhibits for the purpose of demonstrating to students. So the Museum of Antiquities and Arts was established to support the educational process among the students of History and Philology Faculties. The museum's collections were formed in various ways, including unique items, which were bought from collectors in Moscow and St. Petersburg. During the Second World War part of Hermitage collections was evacuated to Perm. After the war, when the funds were returned to Leningrad, the leadership of the Hermitage decided to present with the part of the exhibits the Museum of

Antiquities and Arts at Perm University. Today the Museum has more than 25 thousand storage units. The Museum's storage facility includes the following subject collections of historical and cultural heritage items, that is "Ancient Egypt", "Ancient Greece", "The Fine Arts of Europe" and some others.

Digitization of the museum's exhibits is caused both by the need to make the museum items more available for their use in scientific research and education, and it is also connected with the training of specialists in the field of creating digital information resources of historical and cultural heritage.

At the moment we create 3D models of exhibits of the Ancient Greek collection, which is represented by objects of ancient Greek life from the 6th century BC up to the 2nd century AD.

The most important factor in the project's realization is the implementation of low-budget digitization, which has affected the technical and technological basis of the process. The choice of software was also caused by the special conditions of the developers for the implementation of non-commercial projects in the field of preservation and representation of historical and cultural heritage.

The purpose of this article is to demonstrate the experience to implement low budget digitization, creation and use of 3D models of the antique collection of the Perm University History Museum. The article describes the technological process of 3D models' creation, it also shows ways how to overcome the limitations of the automatic digitization process (correction of a polygonal mesh, texture, etc.), examines ways to verify the correspondence between the created digital copy of the exhibit and the original, and shows the possibilities of using the created collection of 3D models in scientific research, education and popularization of historical and cultural heritage.

2 Related Work

Creation of high-quality 3D photogrammetric models of objects of historical and cultural heritage appears to be at the center of researchers' attention [1–4]. 3D modeling of isolated objects using photogrammetry technology is very relevant with regard to value of sources [5, 6]. Most methods and technologies for creating high-quality 3D models with a high degree of automation are costly, due to the price of equipment (laser scanners) and software. Nevertheless, very low cost digitization technologies with high quality of 3D models are very popular. Recent reviews of low-budget digitization technologies have been published [7, 8], the software based on SfM and IM technologies has been analyzed [9], their advantages and disadvantages have been examined [10]. Some of the identified limitations can be overcome by using the methods described in this paper.

The development of the information environment in the field of historical and cultural heritage is accompanied not only by the increase in the quantity and quality of these resources, but also by the creation of digital cultural heritage services related to heritage documentation, data organization, and the simplified search for the necessary resources with the help of aggregators (for example, Europeana [11]). Recent questions about the ways to use in the future the created digital resources of historical and cultural

heritage have become more urgent [12]. Among these methods one can single out the scientific direction of use (including reconstruction), educational, social, including the popularization of history and historical and cultural heritage, commercial as well as creative directions, which are becoming more and more in demand [13]. The project, realized at Perm University, connected with the creation and use of 3D models of exhibits from the collection of the History Museum has a high potential for diversified use, which is shown in this article.

3 3D Model Creation

3.1 The Center for Digital Humanities. Educational Courses in Preservation and Representation of Historical and Cultural Heritage

The Center for Digital Humanities at Perm State University [14] deals with the application of information technologies in humanitarian research and education. The staff of the Center have developed and now conduct a whole range of educational courses on the topic of preservation and representation of historical and cultural heritage based on information technologies. The basic course “Information technologies in Humanities research” is taught at all faculties of the university. One of the sections of the course is devoted to the preservation and representation of the historical and cultural heritage on the basis of ICT, which also includes the demonstration of the possibilities of 3D modeling technology to address these issues. So students learn to create models on the basis of real valuable objects from the collections of the Perm University History Museum.

Perm State University also ensures a program for the preparation of masters in “Digital technologies in sociocultural and art practices” in the direction “Culturology”. The curriculum provides several courses related to the preservation and representation of historical and cultural heritage based on information technology. In particular, the course “Fundamentals of 3D modeling and virtual reconstructions”, related to the creation and visualization of 3D models of cultural heritage, has been created. The approbation of this course was connected with the experience of creating 3D models of the antique collection’s exhibits.

The important condition for the development and implementation of the training course was the realization of low-budget digitization, which influenced the choice of software and technological basis of the process.

3.2 The Program-Technological Basis of the 3D Modeling Process

To create 3D models, photogrammetry technology was chosen [15], based on the principle of constructing realistic 3D models based on photographic images of the subject.

As a specialized software for creating 3D models, 3DF Zephyr Lite Steam Edition1 and Agisoft Photoscan have been chosen. While choosing software, the quality of 3D capture played a decisive role, as well as the special conditions for acquiring licenses for non-commercial use when implementing projects in the field of historical and cultural heritage.

The following equipment has been used for shooting:

- digital camera Canon EOS 600D Kit 18-135 (on a tripod);
- three LED lamp installations (left, right and top);
- rotating platform with a linear surface;
- softbox.

The usage of LED SMD projectors “Soyuz” allowed us to minimize the thermal impact on the exhibits.

Necessary items when shooting were also clean gloves to protect the subject from possible exposure to grease and dirt from the hands.

3.3 Photogrammetric Image Acquisition and Data Processing

The process of creating 3D models is determined by the selected technology and includes several stages, the first of which is photographing the object.

The fundamental requirement for photographic images for subsequent photogrammetric processing is a high degree of overlap to ensure the full coverage of the source image, since points in a sparse point cloud are created from coincidences of similar pixels identified simultaneously in several photographs.

Exhibits of collections refer to isolated objects, and they have been shot from several camera positions to match the model better to the original. Photographing has been conducted by a 360° rotating platform with a graduated and graded surface.

The basic settings of the camera for shooting were as follows:

- Minimum ISO value (400);
- size image (RAW) 5184 × 3456.

After the photography, the photos of the objects were uploaded for photogrammetric processing of digital images, and then the cameras were calibrated and aligned in automatic mode (Fig. 1).

In some cases, the automatic camera alignment process did not yield positive results, and it was required to set the markers for re-alignment manually and to obtain a more accurate location of the points.

The process of aligning the cameras is accompanied by the construction of the initial sparse point cloud, on the basis of which the process of dense point cloud generation goes on. Dense point cloud was edited, for example, extra points were removed.

The next step is to calculate the data of dense point cloud and the formation on this basis of a geometric polygonal mesh.

The last stage of the model construction is the creation of a texture and the acquisition of a realistic model based on the data of 2D photographic images.

Some of the created models required correction of the external geometry because there were inaccuracies in the formation of a polygonal mesh. So, for example, the greatest difficulty was represented by the construction of a three-necked neck of an antique vessel of oenochoe and the external geometry of the vessel was corrected in the program for editing 3D models of MudBox. With the tools of the application, the surface of the neck was smoothed and the thickness of one of the petals was increased to match the original.

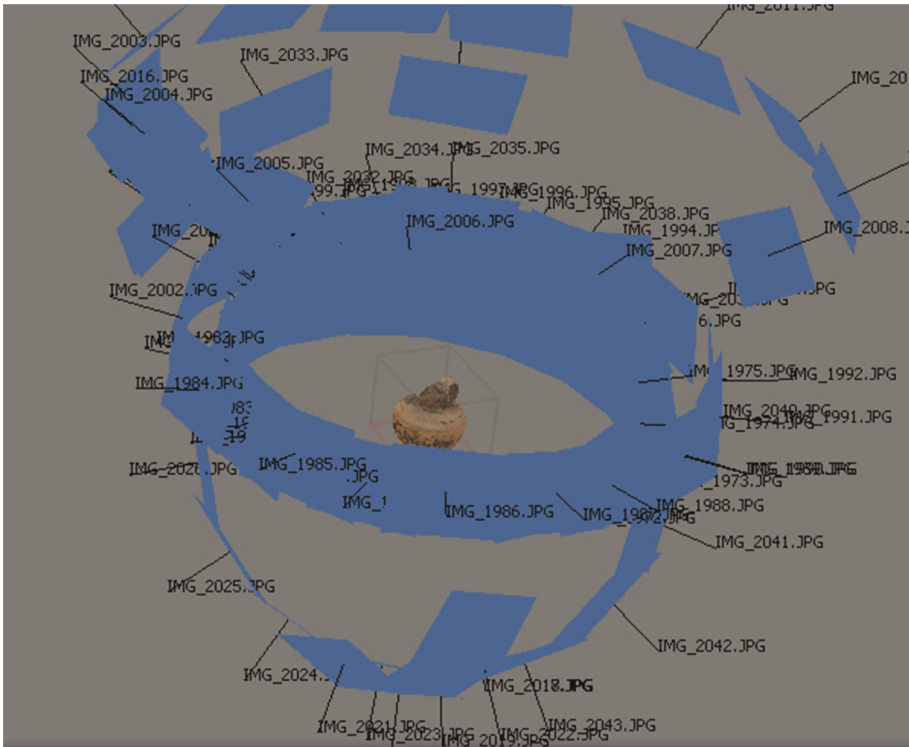


Fig. 1. Aligning cameras and building a sparse point cloud in Agisoft PhotoScan

3.4 The Accuracy of the 3D Models. Problems of Digital Reconstruction of Historical and Cultural Heritage Objects

The maximum correspondence of a digital copy to the original is a significant task of 3D reconstruction of historical and cultural heritage objects. However, the solution of this problem has a number of difficulties that require a special approach. We enumerate some of them.

The photogrammetric modeling technology based on photographic images of the object allows us to reconstruct the external shape of the object with high accuracy. However, the complexity of the external geometry of ancient Greek vessels often makes it impossible to make a series of photographs with 100% capture of all parts of the object, since the part the object's surface remains in the "blind" zone. Most often, such zones are in places difficult to photograph. For example, the upper part of the aryballos with the image of the deer has a complex geometric shape in the form of a notch under the visible part of the neck. The survey of the vessel in the horizontal position did not allow full fixing of this part. Therefore, it was required to use the 3DF Zephyr tool to close holes in a hard-to-reach zone, and MudBox to smooth the surface and correct the shape of the part of the "blind" zone (Fig. 2).

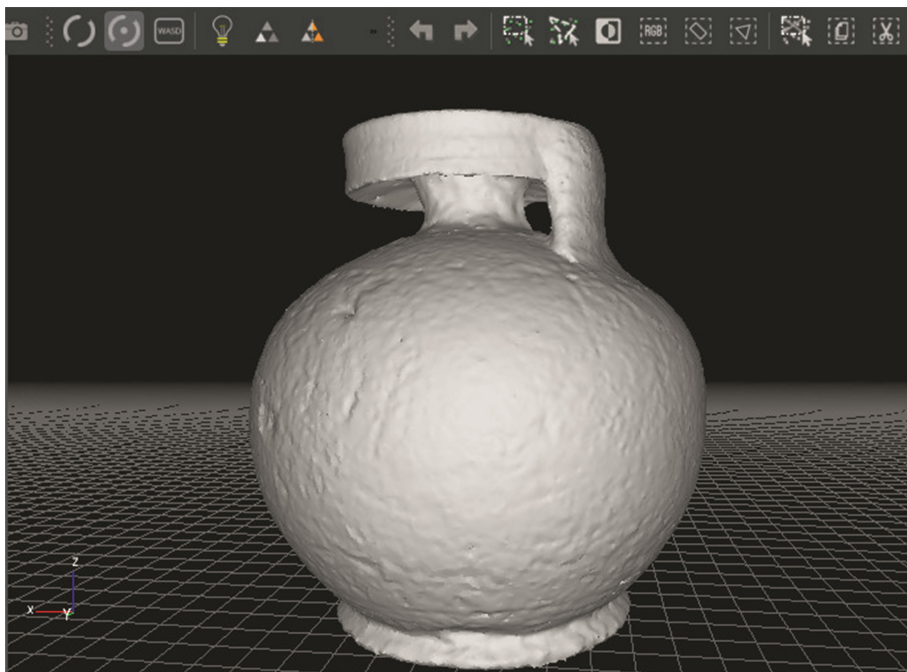


Fig. 2. Mesh of aryballos under correction

Another problem is the technological limitations of the photogrammetric technology based on image acquisition, when black, shiny, lacquer and some other objects can not be correctly counted by the program. It is more effective to use the photogrammetric technology with a 3D laser scanner that partially removes these limitations, but we cannot use such equipment because it is too expensive for a low-budget project.

However, there are low-budget methods that partially allow to overcome the difficulties with the processing of black and lacquered items without using a scanner [16]. So, we used talc while processing and photographing black lacquer products. It reduced the surface glitter and obtained better images. The experiment showed ambiguous results. On the one hand, it was possible to build a 3D model with a sufficiently high quality of external geometry. On the other hand, the texture of the vessel was less realistic and different from the original. This discrepancy was corrected somewhat with the help of the Adobe Photoshop graphics editor.

Vessels are complex objects for 3D modeling, because we have to recreate both their external and internal geometry. So the task is to reconstruct the invisible (inner) part of the object. Most of the information resources created for the representation of the historical and cultural heritage represent vessels with inaccessible inner contents (vessels with narrow necks, for example) only in the form of 3D models with a reconstructed exterior. Reconstruction of the inner part in these cases is not carried out, visible holes in the form of a model either close [17] or leave opened [18].

Another important problem of matching a digital copy to the original is the quality of the color rendition, tint and contrast, which must be controlled during 3D modeling. Color quality control, tone mapping and contrast control are subjective in nature, since visual colour comparison of a digital copy and the original is carried out by a person. For these purposes, a color scale is used, which reflects the system of colour shades.

Thus, the created 3D models have a high degree of compliance with the originals.

4 Publication of 3D Models

The creation of 3D models is accompanied by the export of a polygonal mesh and the texture of objects in formats intended for publication of models and their review by the user. 3D models were exported as a package of formats - OBJ (file with 3D geometry data), MTL (which completes OBJ file with information about the materials used in this model) and JPEG (image texture model). During the export process, the 3D model was saved with the resolution that is optimal for online publication and subsequent comfortable download by the user. A master copy of the model with the highest resolution was also exported.

Our approach is to use existing free platforms for the publication of 3D models to maximize the availability of digitized items of historical and cultural heritage.

The created models are published on the Sketchfab platform [19], which has a whole set of functions for displaying objects. Some of the functions are control of the main parameters of the scene (the orientation of the object, field of view, background, etc.), the possibility of operating with light when the 3D model is displayed. The important function is the adjustment of materials, which provide the ability to manipulate the intensity of color and glitter, which allows you to display the luster of lacquered objects more realistically. Other settings for displaying the 3D model allow you to operate with the image grit, sharpness, to change the color balance, etc.

It is also possible to arrange annotations describing the details and features of the model elements, which is a significant tool for working with historical and cultural heritage and allows the user to familiarize themselves with the subject and its features.

The information resource has been developed on the website of Perm University Museums [20] to demonstrate the created digital museum objects on the Sketchfab platform.

5 The Usage of 3D Models' Collection

5.1 Usage the Collection in Humanitarian Research

The creation of the exact model, the most appropriate to the original, is a scientific task. The process of creating an external geometry is described above, while the reconstruction of internal geometry is still in the process of searching for optimal solutions. The restoration of the internal geometry of the vessels is carried out on the basis of the study of scientific literature devoted to the analysis of antique vessels of various types [21]. Verification of the internal structure is also possible on the basis of the exhibits with

missing fragments stored in the Museum, and these fragments can be recovered due to the high accuracy of the internal geometry of vessels of different types. Accuracy for constructing the internal geometry of the vessel will allow recreating the whole appearance of a real vessel, and will also become the basis for the accuracy of the conducted experiments of the object's domestic usage.

The possibilities of scientific use of the created collection of 3D models are related both to the study of individual subjects and the collection as a whole. The study of museum subjects is important because of the lack of information about the objects and their origin. The creation of a collection of 3D exhibits, which are available online, allows these exhibits to be introduced into scientific circulation as historical sources for a broader research audience. The analysis of the vessels' symbolism, the study of the origin, the interrelationships of the objects of the collection in the world context with similar objects in other collections will allow to answer many important questions about ancient history, culture and its distribution in the world.

5.2 Educational Process

There are several basic methods of application of these 3D models in the educational process. The original purpose of creating the Museum of Antiquities and Arts at Perm University was an object demonstration of collections to students. 3D modeling, the availability of online collections allow this process of demonstration to be more detailed and convenient in studying.

The 3D models can also be used to study real domestic use of objects, reconstruction of the everyday life of an ancient Greek two thousand years ago. In this regard, the study of the everyday history becomes more vivid and lively.

The process of creating 3D models of the collection's exhibits is important in the training of specialists, who work with historical and cultural heritage - historians, restorers, creators of scientific digital content based on historical resources. It is important to study modern standards for the creation of historically-oriented information resources, to train how to work with specialized software, including those related to 3D modeling. The experience of the Center for Digital Humanitarian Studies at Perm University shows the effectiveness of this approach.

5.3 Historical Reconstruction of Object's Everyday Use

The ancient collection of the Perm University History Museum contains real items of ancient Greek life, including lamps, vessels of different types, shapes and sizes, having different purposes. The use of certain objects is obvious, whereas the ways in which others were used are not so obvious and cause many questions about its usage, traditions and application.

One of such items is the oenochoe, the 3D model of which has already been created and it is situated in a virtual collection on the museum's website [22]. This vessel was used for drinking wine and served for pouring wine mixed with water into kylikes for its direct consumption. Oenochoe has a three-petalled structure of the corolla (the top of the vessel). We cannot clearly explain the purpose of these petals. It is possible to

assume several variants of its practical designation. First, such a structure can be explained from an aesthetic point of view, at the time when beauty and grace of execution were of great importance. On the other hand, the main difference between oenochoe and other vessels is that three-petalled structure of the neck.

Therefore, one can assert the practical significance of this particular structure. The question arises, how the pouring out of liquid from the petals of the vessel took place. Perhaps the oenochoe served for simultaneous pouring into three other vessels, or the liquid was poured into the vessels in turn, and this order depended on the inclination of the person's hand. At the same time, it was important not only how the liquid came from one vessel to another, but also the pose of a person who poured and other circumstances, the study of which was an important and interesting part of the history of ancient Greek's everyday life.

Another everyday item is a lamp, the 3D model of which is also created and available online [23]. Obviously, the lamp was used for lighting. At the same time, there are many questions about the appointment of the lamp, its wick, its material and thickness, the quantity and quality of oil, the time and intensity of combustion, the size of the illuminated space, etc.

A series of experiments with imitation of its real household usage will help to answer all these questions.

Reconstruction of antique objects' everyday life requires a comprehensive study of these processes with the involvement of scientific literature and historical sources, as well as a materialized copy of the subject. 3D printing of objects of historical and cultural heritage is one of the possibilities to create such copies. Modern 3D printing technologies allow you to copy not only the subject itself, but also the image on it.

5.4 Popularization of Historical and Cultural Heritage. Printing 3D Models on a 3D Printer

The creation of 3D models' collections opens wide opportunities for popularization of historical and cultural heritage among various categories of the population - school-children of different ages, students, various categories of adults. Such opportunities include carrying out various activities with demonstration of models, including public lectures and interactive activities.

3D printing of exhibits will allow us to carry out public events with demonstration of real use of subjects of Ancient Greek way of life. Different forms of interaction between researchers and museum visitors are possible. A special role is played by the possibility of discovering the historical and cultural heritage for a visually impaired audience, when one can touch objects and try them in action.

The essential complexity of 3D printing of 3D models is the search for suitable materials for printing, so that the printed model is close to the original not only in form but also in appearance (color, texture, etc.) and other characteristics (weight, for example). Existing 3D printers allow us to use gypsiferous materials and it is possible to print colour images on them. However, gypsum is short-lived, it is not resistant to external environment (heat, moisture). Therefore, it is necessary to solve a whole complex of questions about suitable equipment and materials used.

6 Conclusion

Exhibits of the ancient collection of the Perm University History Museum have a significant historical and cultural value. The creation of 3D photogrammetric models of exhibits and their publication online improve access to historical and cultural heritage items for their subsequent use. Prospective directions for the secondary use of digital items are scientific study of exhibits, use in educational activities in the training of specialists in the field of Digital History and as illustrative material, as well as solving the problems of historical reconstruction of objects' domestic use and popularization of historical and cultural heritage among various categories of the population.

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