DIGITAL ARCHAEOLOGY

CREATION AND PRESERVATION OF DIGITAL CULTURAL HERITAGE

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Abstract: Cultural heritage documentation importance is recognized and supported at international level, the continuous development of new technology is increasing the pressure to document and preserve digitally.
In this paper we briefly review the methods that are commonly used to create digital cultural heritage. The storage solutions have also been reviewed to ensure that the digital content is well preserved. The creation and preservation of digital cultural heritage involves three important aspects: the three-dimensional digitization, data storage and data management.
Keywords: cultural heritage, laser scanning, CAD, photogrammetry, preservation

Introduction

All around the world heritage sites are being affected from natural disasters, weather changes, wars, and human negligence. Cultural heritage assets received a lot of attention recently from the authorities and they benefit from advances made in imaging, sensory and computer processing.

At the moment cultural heritage assets documentation is well recognized and there is an increasing pressure to document and preserve them digitally. As presented by Neamțu, C., Popescu, D. and Mateescu, R.[1], accurate 3D representations of cultural heritage assets are valuable for conservation, scientific study, and education.

Driven by progress in data acquisition systems and data processing capabilities, the 3D virtual model creation is currently receiving a high amount of attention from researchers, many computer graphics artists and 3D scanning specialists have been involved in the 3D digitization of cultural heritage.

As shown in the Digital Agenda for Europe[2], digitizing Europe`s cultural heritage and making it accessible online, preserving it for future generation is one of the challenges of the Digital Agenda for Europe.

The European Commission Recommendation[3] of 27.10.2011 regarding digitization and preservation of cultural heritage invites Member States to:

• Put in place solid plans for their investments in digitization (recently estimated at 100 billion €). The Recommendation spells out key principles to ensure that such partnerships are fair and balanced.

• Make 30 million objects available through Europeana by 2015, including

[1] NEAMȚU/POPESCU/MATEESCU 2011, 79-88.
[2] Accessible on http://ec.europa.eu/digital-agenda/
[3] Accessible on https://ec.europa.eu/digital-agenda/en/digitisation-digital-preservation

all Europe's masterpieces which are no longer protected by copyright, and all material digitized with public funding.

• Get more in copyright material online, create the legal framework.

• Reinforce their strategies and adapt their legislation to ensure long term preservation of digital material.

In the context of digitizing cultural heritage assets and obtaining 3D models the authors of this paper have focused on the digitization of Dacian cultural heritage assets.

As presented by Glodariu, I. and Iaroslavski, E.[4] the Dacian civilization was imposed in ancient Europe through its remarkable achievements in various fields and deeds of arms which have been studied in numerous studies, monographs, works of synthesis, all designed to increase the knowledge on this great and important chapter in the historical development of south eastern Europe.

3D data documentation represents nowadays a critical component that can acquire the shapes and texture with a high precision, allowing the information to be stored and passed to future generations.

As presented by Pavlidis, G., Koutsoudis, A., Arnaoutoglou, F., Tsioukas, V., and Chamzas, C.[5] complete recording of a cultural heritage is a multidimensional process, it involves not only the problem of 3D digitization of objects and monuments but involves aspects such as digital content management and representation.

The digital cultral heritage

3D digitization of cultural heritage assets is considered a common practice. As presented by Gomes, L., Bellon, R., P., and Silva, L.[6] digital preservation of cultural heritage represents an application area for digitization technology whose interest has increased in the past two decades. The main motivations to digital preserve cultural heritage assets are the following:

• To ensure that the shape and texture of an object is not lost in case of damage by accidents or natural causes;

• To allow the dissemination of the 3D models to a large public

To create photorealistic 3D models of real artefacts and environments that have a high degree of fidelity represents a very challenging task that demands advanced knowledge of digitization techniques and computer graphics. The digitization of artefacts and monuments represents a field of continuous research and development, advances technologies in the field of 3D scanning and photogrammetry can change the whole digitization process.

As presented by Koutsoudis, A., Stavroglou, K., Pavlidis, G. and Chamzas, C.[7], 3D content has become very popular not only due to the technological trends (e.g. 3D films, computer games, virtual reality and augmented reality equipment) but also because it provides better comprehension of the visual content. Currently there are research projects such as 3D Icons[8] (built on the results of CARARE and 3D-COFORM) which aim to bring 3D architectural and 3D archaeological content to the public through the Europeana[9] platform.

Since there are more reliable methods to create 3D models for different cultural heritage assets, a large amount of projects based on 3D digitization have emerged around the world.

The work presented in this paper is part of the volunteer based project Virtual Ancient Dacia[10], a collaboration project between Technical University of Cluj-Napoca[11] and National Museum of Transylvanian History of Cluj-Napoca[12] that aims to digitally reconstruct Dacian cultural heritage assets.

The most common methods to digitize cultural heritage assets to provide 3D models are the following: laser scanning, 3D modelling, digital sculpting and photogrammetry.

Laser scanning

Laser scanning is based on a system that uses a light source and an optical detector. The laser emits a light source which usually is in the form of a line, this is projected on the surface of the object and an optical detector detects this line. This process usually uses the triangulation principle, and the system is able to extract the shape of the scanned object.

Traditional measuring techniques are often imprecise and complicated. Using 3D laser scanners the morphological characteristics on an artefact or monument can be acquired and measured with a very high accuracy.

Acquisition of real artefacts and monuments using 3D scanning technology generates enormous quantities of 3D data. Most scanners create large unstructured point clouds that require additional post processing.

3D scanning has taken on a new dimension in coordinate measuring technology using mobile hand-held laser scanners that are easy to operate in different remote areas such as an archaeology site.

During 3D scanning acquisition different problems caused by the hardware optical limits can appear. 3D scanners give notoriously poor results if used to scan black and shiny surfaces, because the surfaces tend to absorb the light beams and prevent the point acquisition. These problems can be reduced by applying a coating layer using a CAD/CAM laser scan spray. This spray enhances the readability of the CAD/CAM scanner laser light by reducing the reflective properties of the material. Its ultra-fine 10-micron particle size allows the mechanism to read the die surface properly and accurately. This spray is washable, but needs more care to be removed, especially into rough surfaces.

Two portable laser scanners have been used to digitize a high amount of Dacian artefacts for the Virtual Ancient Dacia project. The first scanner is a hand held VIUscan[13] laser scanner.

VIUscan is a portable device that not only captures the shape of an object, but it can also record the surface texture. The main advantage of this scanner is that it can acquire the shape of a real artefact relatively quickly. On high resolution a small artefact (around 100 mm) requires about 20 minutes. All the digitized artefacts have been scanned using the highest possible resolution. This scanner is creating uniform

[4] GLODARIU/IAROSLAVSKI 1979
[5] PAVLIDIS/KOUTSOUDIS/ARNAOUTOGLOU/TSIOUKAS/CHAMZAS 2007, 93-98.
[6] GOMES/BELLON/SILVA 2014
[7] KOUTSOUDIS/STAVROGLOU/PAVLIDIS/CHAMZAS 2012, 187-194.
[8] Accessible on http://3dicons-project.eu/
[9] Accessible on http://www.europeana.eu/
[10] Accessible on http://vad.utcluj.ro/
[11] Accessible on http://www.utcluj.ro/en/
[12] Accessible on http://www.mnit.ro/
[13] Accessible on http://www.aniwaa.com/product/creaform-viuscan/

polygonal meshes and it is equipped with a camera that simultaneously records the texture of the scanned surface and positions it over the matching polygons. It can be operated in remote areas such as the Sarmizegetusa Regia archaeological site. This is an isolated area that is not connected to electricity. The scanner and the laptop used for the digitation were powered by a diesel generator and are presented in Figure 1.

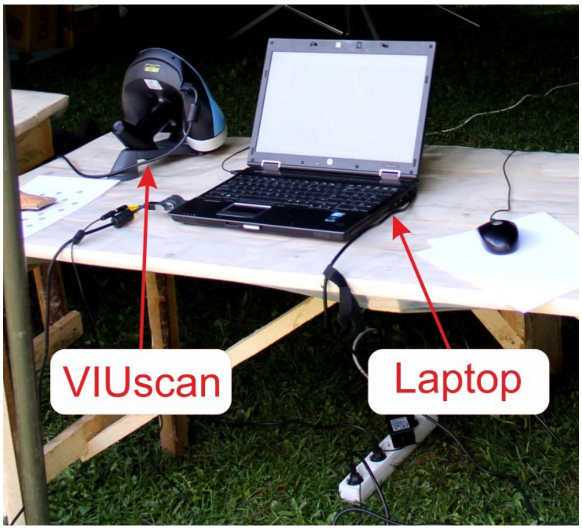

Figure 1. Hand held laser scanner used to digitize Dacian artefacts

Different artefacts have been digitized such as the T-shape nail illustrated in Figure 2. This iron artefact was made by hammering, hence the irregular section of the body. The dimensions of this T-shape nail are 247,018 mm in length, 61,888 mm in width and 11,945 mm in height. VIUscan is a scanner that can be constantly moved around the object during the digitization process. It uses a network of positioning markers (small reflective dots) to estimate the location and orientation. For small objects the reflective dots are positioned around the object but for large objects the markers can be positioned on the object and then the object can be rotated during the scanning process.

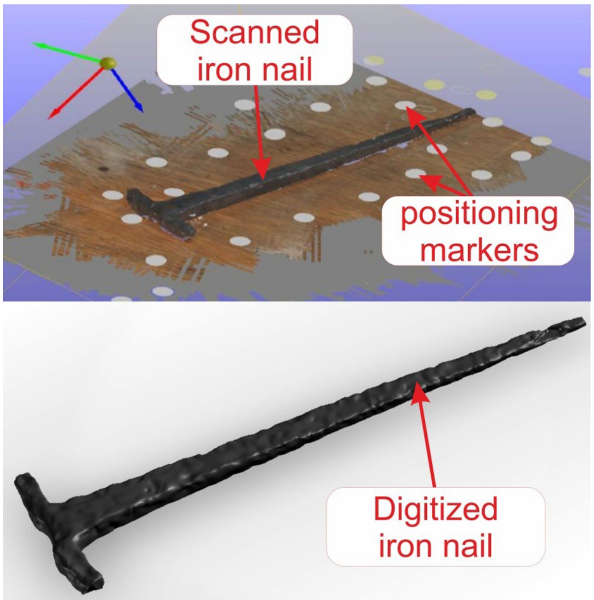

Figure 2. Digitized T-shape Dacian nail scanned with VIUscan

The other laser scanner, Kreon Zephyr KZ-50[14] was mounted on the Stinger CMM II[15] which is a portable coordinate measuring machine. This scanner has been used only in indoor scenarios. The equipment is very bulky and relatively hard to transport, also the range of the arm is limited. The Kreon Zephyr KZ-50 is not suited for large objects or for outdoor digitization.

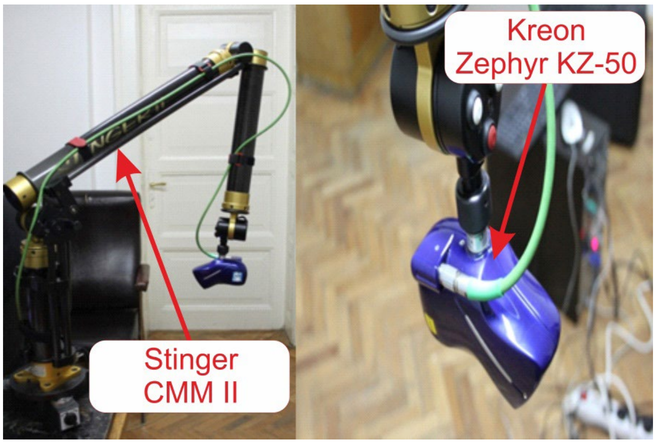

Figure 3. Kreon Zephyr KZ-50 laser scanner mounted on the Stinger CMM II

This scanner creates non-uniform cloud, and it can acquire 30,000 points/second. A large amount of iron artefacts have been digitized for the Virtual Ancient Dacia project using this scanner. The main disadvantages of this scanner it cannot acquire the texture of the object.

The Dacian forges had an incorporated iron guarding element for the bellows. The forge was constructed from clay, and the role of the iron guard was to support and guide the bellows system. The digitized forge iron guard is illustrated in Figure 4a. The digitized model has 1.204.920 point the point cloud is presented in Figure 4b. Figure 4c illustrates the 3D reconstruction in wireframe of the Dacian forge. The clay forge was modelled using CATIA V5R21.

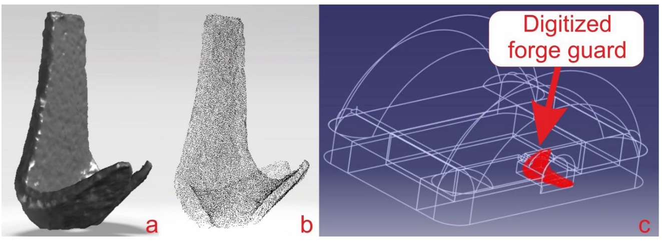

Figure 4: (a) The digitized forge iron guard, (b) the point cloud of the iron guard (c) The 3D reconstructed Dacian iron forge that includes the digitized iron guard

A high amount of iron artefacts have been digitized using the two laser scanners mentioned above. Figure 5 presents the information regarding an iron hammer. The hammer differs from the sledge hammer not only in size but also in form.

The dimensions of this digitized iron hammer are: 162,154 mm in length, 81,327 mm in width and 80,834 mm in height. This is a massive hammer, almost as big as a sledge hammer.

[14] Accessible on http://www.kreon3d.com/zephyr/
[15] Accessible on http://www.cmmxyz.com/romer-stinger-ii-12-arm

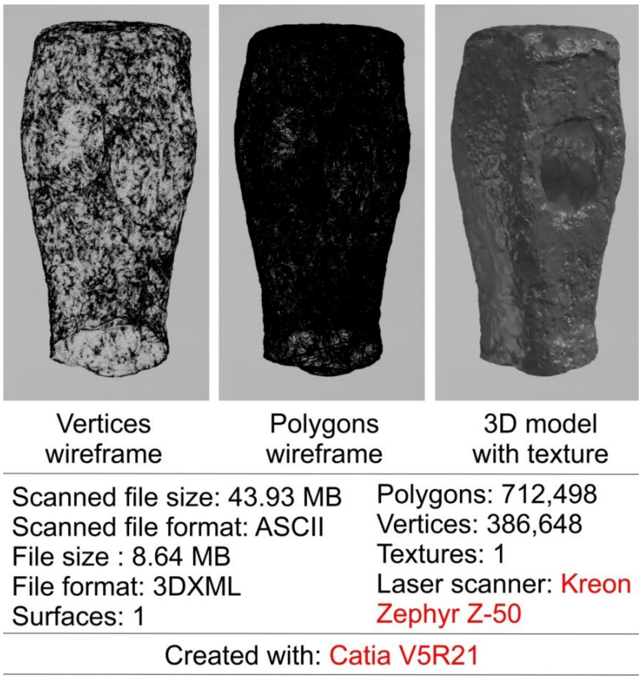

Figure 5. Digitized Dacian iron hammer

A digitized Dacian sledge hammer is presented in Figure 6. The dimensions of this sledge hammer are: 205,417 mm in length, 77,735 mm in width and 80,461 mm in height.

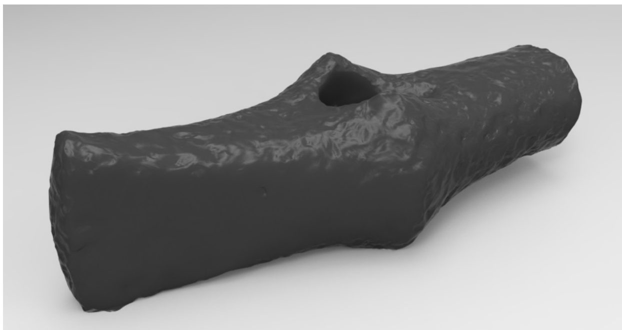

Figure 6. 3D scanned Dacian Sledge hammer

3D modelling

Computer-aided design modelling is a process of developing a mathematical representation of a 3D object or surface; this is done using specialized CAD software.

CAD modelling makes use of empirical and topographic techniques to create the 3D representations. During an empirical recording different measurements are taken (by hand) of distances between characteristics points on the surface of the monument. This method is simple and productive and of low cost. Advanced measurement tools such as laser measuring tools can be used to increase the accuracy of the measurements.

The digital reconstruction of the Dacian blacksmith workshop from Căprăreața was done using 3D CAD modelling using CATIA V5R21[16]. As presented by Glodariu, I.[17], the blacksmith workshop was located on a south hill from Grădiștea, east from the sacred area and archaeologist have discovered this workshop archaeological site in the spring of 1971, a high amount of iron bars, tools and other blacksmithing materials were located around the site.

The documentation regarding the wooden structure of the workshop is limited. The main reference for a Dacian blacksmith workshop is presented in the History-Archaeology Museum from Târgu-Mureș[18], a photograph of this illustration from the museum is presented in figure 7.

Figure 7. Illustration of a Dacian blacksmith workshop from the History-Archaeology Museum from Târgu-Mureș

The first step was to create the four wooden poles. The diameter of each column was set to 300 mm and the distance between the centres of the wooden poles to 4000 mm for the length of the workshop and 3000 mm for the width.

Horizontal beams have been modelled in the form of dovetail joint. The beams have a 5 mm distance between them so that the smoke created by the forge can be evacuated more easily from the workshop.

The virtual reconstruction of the Dacian blacksmith workshop from Căprăreața is presented in figure 8.

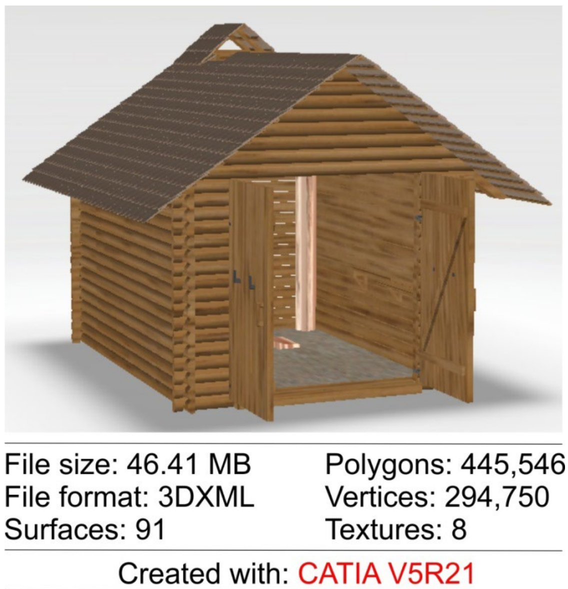

Figure 8. The virtual reconstruction of the Dacian iron workshop

[16] Accessible on http://www.muzeumures.ro/
[17] GLODARIU 1975, 107-133.
[18] Accessible on http://www.3ds.com/products-services/catia/portfolio/catia-v5/catia-v5r21/

With the 3D model of the Dacian workshop created, a virtual environment has been created to better display the blacksmith workshop (Figure 9). In a virtual environment additional models have been added individually to enable better animations and annotations. The virtual environment was created by Neamțu, C., Comes, R., Mateescu, R., Ghinea, R. and Daniel, F[19], additional models have been laser scanned, such as the hinges, nails, staples, anvils, pliers, etc. Other models are a combination of 3D scanned models that have been assembled with 3D modelled elements. These elements are the following: the clay forge, the bellows and the tools that have wooden handles.

Figure 9. 3D scanned model of a Dacian sledge hammer

Digital Sculpting

Digital sculpting represents the use of software that offers tools to push, pull, smooth, grab, pinch or otherwise manipulate a digital object as if it were made of a real-life substance such as clay. Digital sculpting is different from 3D modelling, they are both modelling methods that are done digitally using computer software but the tools and methods are completely different.

The 3D model of the Dacian clay medallion was sculpted using Autodesk Mudbox 2013[20]. The clay medallion photograph was overlapped over an initial cylinder primitive shape allowing the digital sculptor to sculpt more precise.

Digital sculpting applications combine 3D sculpting, texturing and painting. For the Dacian medallion the projection painting method has been used to apply the texture from the photograph of the medallion to the 3D digital sculpted model. The initial photograph, the digital sculpture and the final model that combines the texture from the photograph and the 3D model are illustrated in Figure 10.

More precise results can be obtained using laser scanning techniques or photogrammetry. But if the artefact/monument is damaged or incomplete digital sculpting represents the best solution to digitally reconstruct the missing details. For the medallion the 3D model had only 251,235 polygons but digital sculpting software such as Mudbox can subdivide each polygon in four other polygons using simple algorithms allowing the resolution to be increased therefore details can be sculpted smoothly.

[19] NEAMȚU/COMES/MATEESCU/GHINEA/DANIEL 2012, 303-311.
[20] Accessible on http://www.autodesk.com/products/mudbox/overview

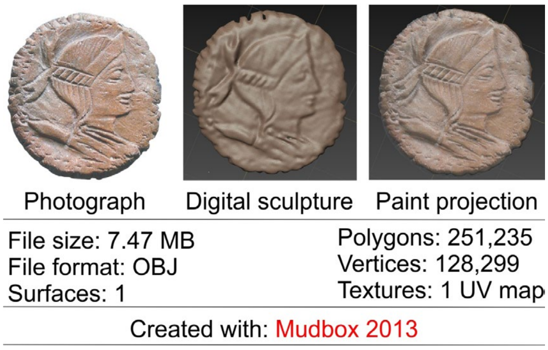

Figure 10. Digital sculpture of the Dacian medallion in Mudbox software using a photograph as reference and texture

The major limitation when subdividing a 3D model in digital sculpting is the processing capability of the computer.

Photogrammetry

With recent developments in computer and information technologies, this well-known traditional method has been adapted resulting digital close-range photogrammetry. This digital method offers new opportunities such as automatic orientation, measurement procedures, generation of 3D vector data, digital surface model and 3D surface texturing.

There are many photogrammetry software that use automatic orientation systems. Autodesk 123D Catch[21] is photogrammetry software that can be installed on a computer. It has mobile device applications for IOS and Android that allows the users to use their smartphones to take photographs and upload them to Autodesk 123 Catch cloud system to generate the 3D models. Professional DSLR cameras provide better results when working with photogrammetry since the pictures acquired with professional cameras contain more information.

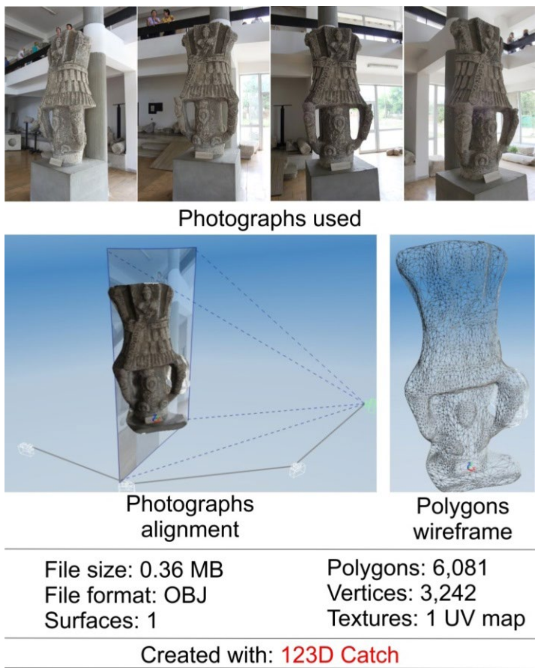

Figure 11. Small monuments from Adamclisi created with Autodesk 123D Catch

[21] Accessible on http://www.123dapp.com/catch

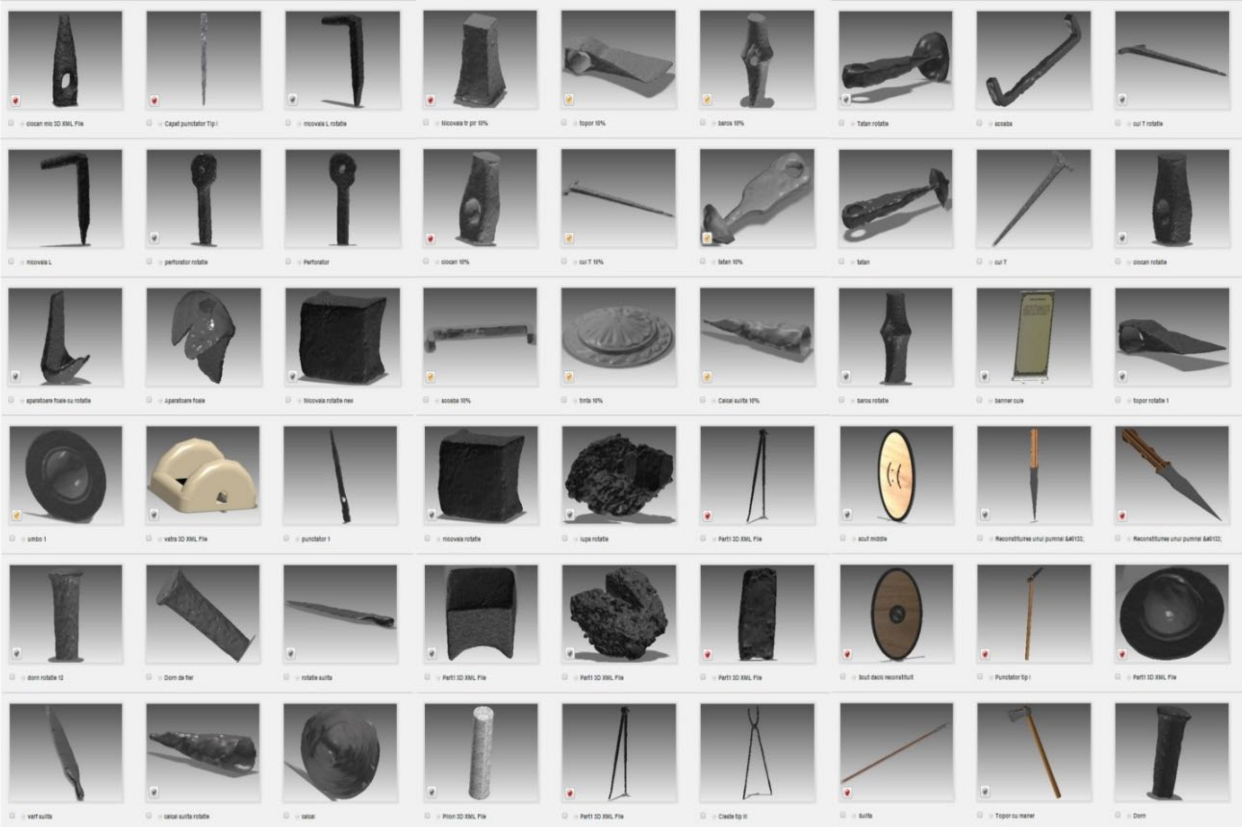

Figure 12. Online cloud storage system used for the Virtual Ancient Dacia project

The small monument from Adamclisi has been digitized using this software, Figure 11 presents the photographs used and the 3D digitized model.

For best results it is recommended to shoot a loop of about 20 sequential photographs in small increments around the object and also shoot another loop from a different angle.

After the 3D model is generated it requires additional clean up, this can be done using the web application of the Autodesk 123D Catch software or the file can be imported to a 3D modelling software for further processing.

Photogrammetry represents a technology that can generate 3D digital content very fast compared to the other 3D digital content creation methods. But the precision is much lower then the precision of the 3D scan method. Recent research and development in the field of photogrammetry increased the precision of this method making it a viable solution to create 3D digitized content suited for cultural heritage assets.

Digital storage and access

the digitized 3D models created in the Virtual Ancient Dacia project are stored locally and online. The cloud storage system used by us allows user to access special created virtual reality environments that provide additional information regarding each 3D digitized cultural heritage asset.

When it comes to storing data, cloud storage has become the method of choice. Files stored remotely rather than locally have the following advantages:

• **Collaboration** – cloud storage allow multiple users to edit and collaborate on the same file, this eliminates the problem of tracking the latest version or who made what changes;

• **Protection and recovery** – cloud storage systems create backups that are kept in different and secure locations. In the case of a catastrophic data loss the backups will automatically restore the digital content with no downtime.

• **Syncing and accessibility** – The content can be accessed from different devices such as smartphones, tablets, notebooks, desktops and workstations. If the users have internet access they can access any file.

• **Security** – Storing important information in the cloud is often more secured than local storage. Some cloud storage system encrypts the data during transmission, ensuring no unauthorized users can access the files.

• **Manage interactive environments** – Virtual reality and augmented reality applications can be created easier if all the data is stored in the cloud system. The data can be managed easier using this system.

Complex models have been optimized to ensure mobile device compatibility. These files can be accessible using smartphones and tablets. The cloud storage system is illustrated in Figure 12. The initial and the optimized 3D models are stored in the same cloud storage system.

Conclusions

Obtaining 3D digitized cultural heritage content represents a complex process that can be done using different methods. The digitization method depends highly on the cultural heritage asset that is being digitized. Laser scanning and photogrammetry can be used to acquire the shape and texture of existing artefacts and monuments, while 3D modelling and digital sculpting can be used to virtually recreate damaged or incomplete cultural heritage assets.

3D digitization of cultural heritage assets is considered a common practice and represents a critical component that can preserve cultural heritage assets digitally. However there are many challenges and open problems in order to obtain high fidelity 3D models. The research in this field and constant development of the acquisition systems (laser scanning and photogrammetry methods) are constantly improved allowing higher fidelity 3D models to be obtained much easier.

Online cloud storage represents the best method to ensure that the digital cultural heritage data are protected and secured. Since cloud storage creates multiple backups on different locations the files can be recovered in case of catastrophic data loss. Interactive virtual reality applications and augmented reality applications can be created and managed better if the files are stored in a cloud storage system.

In this article we summarize most of the methods available today for 3D digitization that can be applied to create and preserve digital cultural heritage assets, all the presented 3D digitization methods have been used to generate 3D content for the Virtual Ancient Dacia project.

Further research will be devoted to improve the fidelity of the 3D models within this project. Virtual reality application, augmented reality applications and 3D printed replicas of damaged/incomplete artefacts are being developed to ensure the dissemination of this research.

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