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Ana SOLTER & Dubravko GAJSKI

PROJECT "TOWARDS THE VIRTUAL MUSEUM" – EXPLORING TOOLS AND METHODS FOR 3D DIGITALIZATION AND VISUALIZATION

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A 3-year pilot project "Towards the Virtual Museum – 3D-digitalization of A-category objects selected from the collection of Archaeological Museum in Zagreb" has a primary objective to enhance the accessibility of museum collection to a bigger audience, both scientific and the general public. The project goal is to research existing tools and methods for 3D digitalization and visualization of archaeological objects different in size and material. Digital models achieved by 3D scanning techniques will be equally used for virtual reconstruction, making replicas, scientific analysis and detailed damage recordings on objects and monuments.

Key words: 3D digitalization, 3D visualization, 3D scanning, photogrammetry

1. INTRODUCTION

One of the main roles of the Archaeological museum in Zagreb is the presentation of cultural heritage, through exhibitions and projects belonging to the domain of public archaeology and cultural heritage management. Several European projects, for example, MINERVA (libraries) and ATHENA (Museums), have been financed for digitising different type of content and supplying metadata associated with the content. These led to the establishing of Europeana, EU digital platform for cultural heritage, with a goal to digitalise and enhance digital preservation in Europe. Presentation of 3D models has become a highly attractive way to introduce cultural heritage to the audience thus projects like 3D-ICONS were funded to digitise 3D architectural and archaeological monuments and buildings identified by UNESCO as being of outstanding cultural importance. (D'Andrea et al. 2012 :1–4).

The Archaeological museum in Zagreb began a 3-year pilot project "Towards the Virtual Museum – 3D-digitalisation of A-category objects selected from the collection of Archaeological Museum in Zagreb" (further in the text: 3D AMZ) with a primary objective of research in testing existing tools and methods for 3D digitalization and visualization of archaeological artefacts different in size or complexity of shape and material. The end goal of the project is creating a database of highly accurate 3D models.

3D AMZ is a joined project of Archaeological museum in Zagreb, Documentation department and Faculty of Geodesy, University of Zagreb, Department of Photogrammetry and Remote Sensing that started in 2013 and will run for three years. The project is funded by Ministry of Culture of the Republic of Croatia and City of Zagreb,

2. PROJECT OBJECTIVES

Through better virtual communication with the audience, we have an opportunity for worldwide promotion of Croatian cultural heritage and the Museum. Project objective is creating highly quality 3D models of archaeological artefacts and monuments in Museum's collections represented in online databases. The project activities will explore the possibility of creating a digital repository accessible to the public.

The important objective of the project is an interactive digital presentation of archaeological artefacts for the public, both for temporary and permanent exhibitions using 3D models visualizations for specific exhibition projects, both as part of exhibition multimedia displays and web presentation. 3D AMZ aims to explore the optimal methods for visualization and interactive exploration of 3D models. There are different possibilities of representing 3D models to the scientific community, and to a wider audience throughout predefined dynamic visualization. The goal of the project is to choose the most appropriate file format for the recording of 3D models and best software for interactive visualization of 3D models. Also, during the visualization tests, we plan to explore different stereoscopic visualization techniques as a method of interpretation of archaeological artefact.

3. CONTENT

The 3D content which will be created by the project includes A-category objects selected from the collection of Archaeological Museum in Zagreb. Thus, the project will aim to bring to the public most famous museum artefact throughout new technology that will allow better understanding and appreciation of our cultural heritage. In the first stage of the project, we selected 14 archaeological artefact objects different in size and material. At the end of the project, more than 40 3D models will available online.

4. TECHNICAL SOLUTIONS

During the 3D AMZ project we plan to explore up to date 3D methods of measuring, documenting and visualizing of archaeological artefacts (Guidi et al. 2014: 335–346). To avoid any possible damages or other adverse impacts to artefacts measured, only non-contact measuring techniques will be considered, such as 3D laser scanning by the laser scanner and 3D scanning by photogrammetry.

3D laser scanning is accepted widely by the community as the most appropriate measuring technique. The result of 3D-scanning is point cloud. All the points in point cloud have information about position and colour. Although the positional accuracy of the point cloud, gathered by 3D laser scanner is quite high, the quality of colour recorded at each point is very poor. The density of points in point cloud is not high enough to adequately represent textures of scanned artefacts. To improve the quality of 3D-laser scanning and to raise the quality of texture representation the combination of laser scanning technique and photogrammetry gives the best results (Guidi et al. 2013).

The whole process of producing the 3D model of an artefact can be divided into a few steps:

1. The preparation for data collecting. All details of the artefact, important for data gathering are analysed. According to the results, the most appropriate technology was chosen (triangulation scanning or close range photogrammetry), and parameters were set.

2. Data acquisition (by scanning and/or by photogrammetry) in Museum environment. The main challenge is to obtain good results that can guarantee the desired metric accuracy and colorimetric fidelity, without disturbing daily Museum activity by returning artefacts to permanent exhibition as soon as possible.

3. 3D modelling of selected artefact is done in office, not necessary in the Museum. SfM (Structure from Motion) approach automates this procedure significantly. However, the interactive work at the computer to avoid the imperfections of modelled surface is necessary. Thus, it is the most time-consumption phase.

4. The static and dynamic visualization of 3D model is a phase that needs to be well planned and adopted to every particular artefact according to its archaeological interpretation and importance. The active cooperation with archaeologist is necessary for all just mentioned phases, but in this one the role of an archaeologist is crucial.

Although the time of production of detailed metric 3D model depends on many features of model's surface and vary from artefact to artefact significantly, according to our experiences we can predict the production time as follows:

step	procedure	time (hrs)
1	Preparation for data collecting	3-5
2	Data acquisition	2-6
3	3D modelling	3-14
4	Visualization	5-24
	Σ	11 - 49

The values are exact under the assumption that experienced and skilled staff performs all procedures. The presented procedures are explained more in detail, as it follows:

The 3D laser-scanning throughout the first phase of the project was done by triangulation scanner MINOLTA VIVID 9i combined by calibrated digital still camera NIKON D90 equipped with SIGMA 20/2.8 lens. To improve the accuracy of measured data and to speed up the scanning process for the needs of the project special custom rotating black

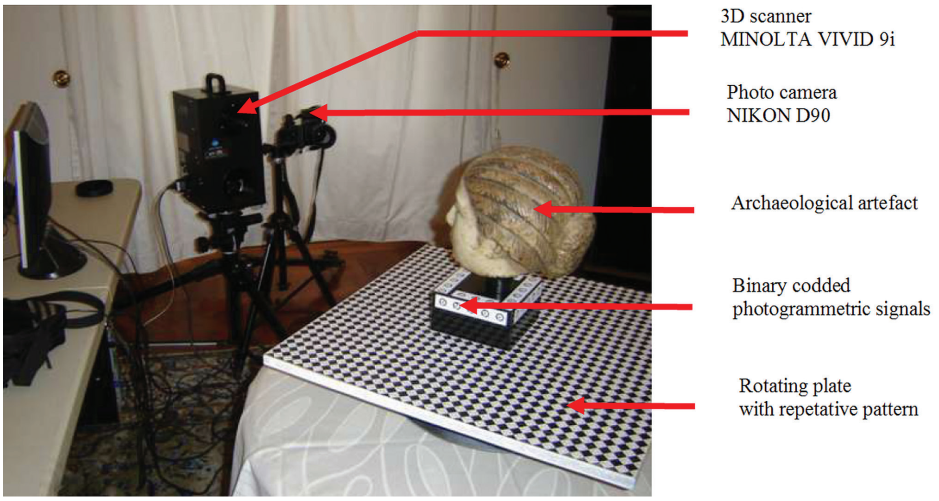

Figure 1. The photogrammetric set (by. D. Gajski, 2013)

Figure 2. 3D-scanning of artefacts displayed in Lapidarium of AMZ (by. D. Gajski, 2013)

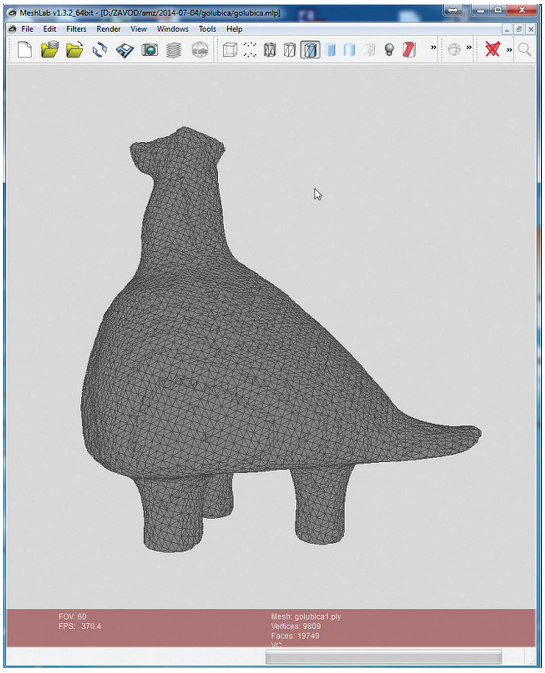

Figure 3. 3D-wireframe-model in axonometry (http://meshlab.sourceforge.net/, D. Gajski)

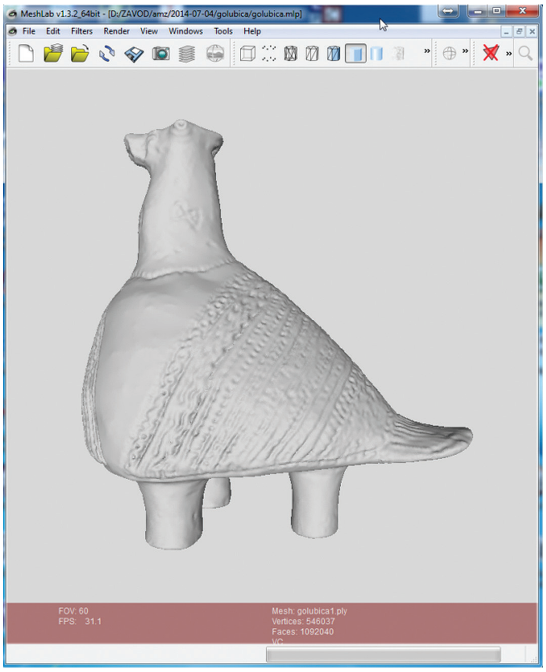

Figure 4. 3D-surface-model in axonometry (http://meshlab.sourceforge.net/, D. Gajski)

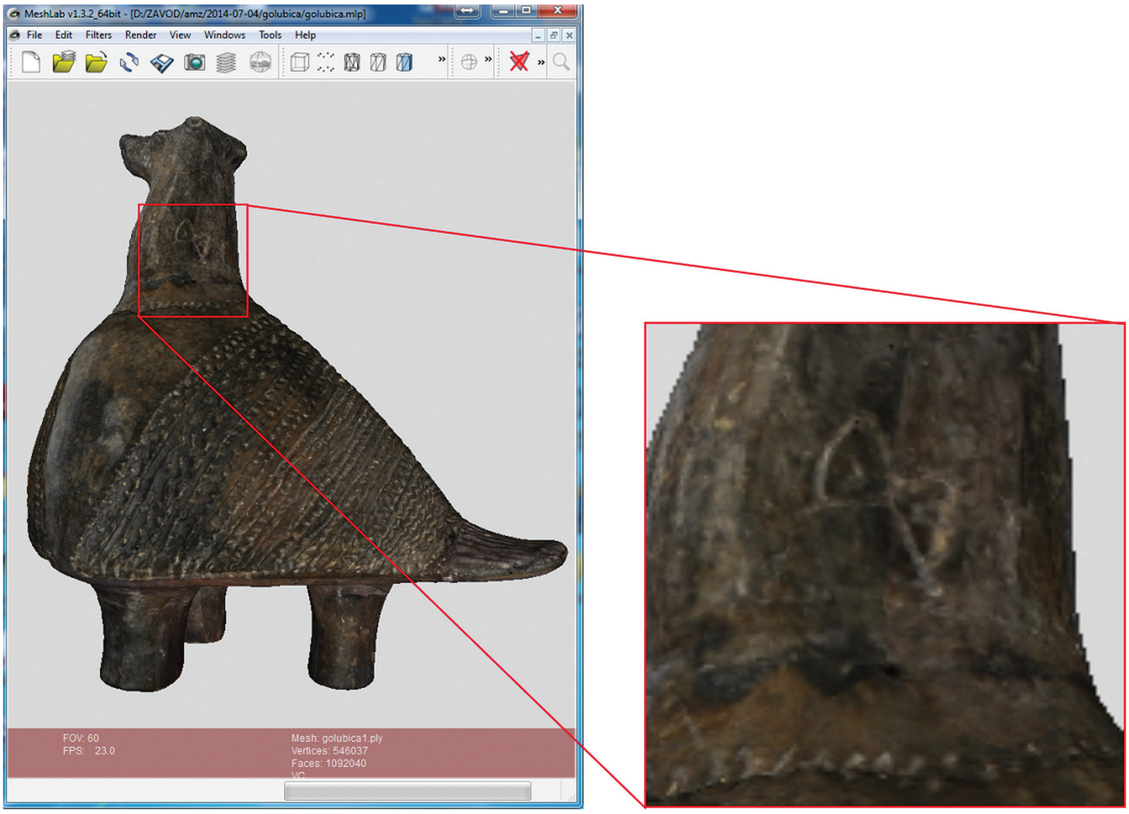

Figure 5. 3D-phototextured-model of artefact (P-Vč 8201) in axonometry with a detail enlarged (http://meshlab.sourceforge.net/, D. Gajski)

and white patterned plate with the binary coded photogrammetric signals was made, devoted to automatic correlation purposes (Fig.1).

Stone artefacts displayed in Museum's Lapidarium could not be placed on the rotating plate, due to their weight and size. Concerning that reason, the photogrammetric signals were placed directly on their pedestal. Instead of rotating the artefact, the laser-scanner and photo camera had to be rotated around the monuments. The artefact shown at Fig. 2 is scanned and photographed in 84 different positions. All the artefacts, except the ones in Museum's Lapidarium, were shot indoors.

After the data collecting phase, the absolute orientation (registration) of every point-cloud was done, followed by pre-processing and modelling of the scanned object (Barilar 2015). This part of the project was done using open-source software MeshLab (http://meshlab.sourceforge.net/) (Fig. 3 and Fig. 4).

3D-models were photo-textured by imaging of photographs taken during 3D-scanning. The imaging was performed according to the rigorous central projection mathematical model. Photo camera was calibrated before imaging so it could reach the high quality of texturing. (Gašparović 2015) (Fig. 5).

Artefacts very small in their size or of extreme transparency (glass, amber), require special approaches to data acquisition as well as additional processing to get high-quality models. The technology of macro photogrammetry applied at measuring of the point cloud of the ancient amber figurine is shown in Gajski et al. 2016.

5. VISUALIZATIONS OF 3D-PHOTOTEXTURED-MODELS OF ARTEFACTS

The detailed and accurate 3D-models of artefacts can make the virtual copy of unique artefact easy accessible to everyone. One can explore and interpret the features of the artefact without time limit at the most comfortable place, work or home. Beside this, people have different needs in the exploration of the 3D-models, according to their interest, professional or private. That's why different visualizations technologies were considered and explored: interactive visualization and dynamic visualization (movie), both in mono- or stereoscopic vision technology.

Interactive visualization

Figure 6. Interactive visualisation of photo textured 3D-model in open-source software CCViewer (http://www.danielgm.net/cc/, D. Gajski)

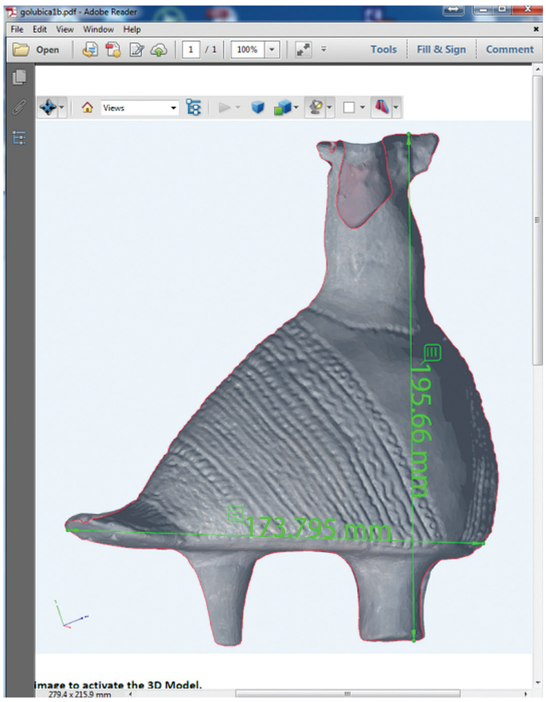

Figure 7. Longitudinal section through 3D-model in free software: Adobe PDF-reader XI (https://acrobat.adobe.com/us/en/products/pdf-reader.html, D. Gajski)

One can choose the position, orientation, and magnification of 3D-model (Fig. 6), or the part of it; that is in the focus of interest of the investigator.

It is possible to resect the model by arbitrary plane and measure dimension between any two points on the model (Fig. 7).

It's all possible by use of freely accessible software (i.e. Adobe Acrobat, Meshlab, CC Viewer, ...) locally at the own computer, or over the internet using just common internet explorer.

Dynamic visualization (movie)

To give the first information about presented artefact, the most suitable method could be a movie presenting the artefact. It's very important that experienced archaeologist is included in the design of video-presentation to ensure that the important features of each artefact are stressed instead neglected. To the video presentation, one can add the basic information of artefact, spoken or written. Such material is very suitable for educational or promotional purposes.

Stereoscopic visualization

The project explores the abilities of the stereoscopy in the visualizing of archaeological artefacts. Several methods of reaching stereoscopic vision are explored, and the technology of active polarized screen and passive polarized glasses is chosen as the best suitable for virtual stereoscopic recordings of 3D models. (Kozić 2015).

Virtual environment

The aim of the project is to place digitized artefacts in a virtual environment as digital assets to allow users to interact with that environment (Ahmed et al. 2014: 149–150). With the help of VR headsets user could be completely immersed within virtual reconstruction and actually have a possibility for "seeing" the past.

6. CONCLUSION

Pilot project 3D AMZ explores different technologies for 3D digitalization and visualization. Each archaeological artefact has its specific challenges and the technology for making high-quality 3D models should be adapted for optimal results. 3D scanning and photogrammetric methods complement each other and substantially reduce the impact of disadvantages of both methods. The focus of the research is to obtain photo-realistic highly quality 3D models of archaeological artefacts that can be available to public, potentially used in schools and other services. 3D AMZ increases access to cultural heritage through use of digital media.

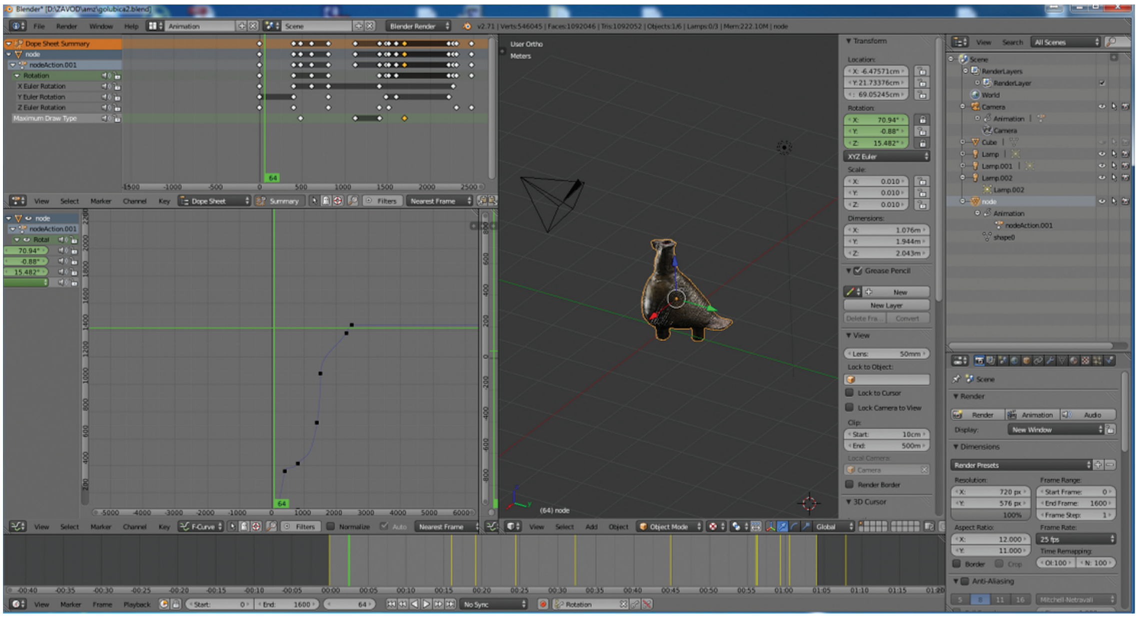

Figure 8. Start of animation procedure using open-source software Blender (https://www.blender.org/, D. Gajski.

The project is still undergoing so in our next phase we will exploit the photogrammetry as the only technology for acquiring 3D models and the usage of low-cost image-based systems for automatic 3D recording (Kernsten & Lindstaedt 2012: 1–10).

3D format provides an attractive way for engaging with a digital cultural heritage which is increasingly popular with museum visitors. 3D AMZ aims to make the generation and manipulation of 3D content in museum community affordable and accessible, allowing museum employees to digitalize the artefacts without the use of high-eng hardware and software.

BIBLIOGRAPHY

Adžić 2015 — Đ. Adžić, *Fotogrametrijska izmjera arheoloških artefakata* (unpublished MA thesis, Faculty of Geodesy, University of Zagreb - Institute of Cartography and Photogrammetry), Zagreb, 2015.

Ahmed et al. 2014 — N. Ahmeda, M. Carterb & N. Ferrisc, „Sustainable archaeology through progressive assembly 3D digitization", *World Archaeology*, 46:1, 137–154.

Barilar 2015 — M. Barilar, *Izrada fotorealističnog 3D modela arheološkog artefakta* (unpublished MA thesis, Faculty of Geodesy, University of Zagreb - Institute of Cartography and Photogrammetry), Zagreb, 2015.

D'Andrea et al. 2012 — A. D'Andrea, F. Niccolucci, S. Bassett & K. Fernie, „3D-ICONS: World Heritage Sites for Europeana: Making Complex 3D Models Available to Everyone", *Virtual Systems and Multimedia (VSMM),* 2012, 1–4.

Gajski et al. 2016 — D. Gajski, A. Solter & M. Gašparović, „Applications of macro photogrammetry in archaeology", *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.,* XXIII ISPRS Congress, Prague, 2016, 263–266.

Gašparović 2015 — M. Gašparović, *Radiometrijsko izjednačenje tekstura fotorealističnih 3D modela*, (unpublished PhD thesis, Faculty of Geodesy, University of Zagreb - Institute of Cartography and Photogrammetry), Zagreb, 2015.

Guidi et al. 2013 — G. Guidi, L.L. Micoli, S. Gonizzi, P. Rodriguez Navarro & M. Russo, „3D Digitizing a whole Museum: a Metadata Centered Workflow", *Digital Heritage International Congress Vol 2.*, IEEE, 2013, 307–310.

Guidi et al. 2014 — G. Guidi, S. G. Barsanti, L. L. Micoli and M. Russo, „Massive 3D Digitization of Museum Contents", in: L. Toniolo, M. Boriani, and G. Guidi (eds), *Built Heritage: Monitoring Conservation Management Research for Development*, 2014, 335–34.

Kernsten & Lindstaedt 2012 — T. P. Kersten & M. Lindstaedt, „Image-Based Low-Cost Systems for Automatic 3D Recording and Modelling of Archaeological Finds and Objects", *Lecture Notes in Computer Science*, 7616, 2012, 1–10.

Kozić 2015 — R. Kozić, *Stereoskopske vizualizacije arheološkog artefakta* (unpublished MA thesis, Faculty of Geodesy, University of Zagreb - Institute of Cartography and Photogrammetry), Zagreb, 2015.

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http://meshlab.sourceforge.net/ (accessed: 14 November 2015)

http://www.danielgm.net/cc/ (accessed: 14 November 2015)

https://acrobat.adobe.com/us/en/products/pdf-reader.html (accessed: 14 November 2015)

https://www.blender.org/ (accessed: 14 November 2015)