EUROGRAPHICS Workshop on Graphics and Cultural Heritage (2016)
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A complete workflow from the data collection on the field to the deployment of a Virtual Museum: the case of Virtual Sarmizegetusa.

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Abstract

This paper presents the first installation produced with the data collected on the ancient roman city of Colonia Dacica Sarmizegetusa: it can be considered a concrete example of a full workflow, from photogrammetric 3D acquisition to gaming experience, able to contribute to the community of experts in the domain of virtual museum. The visualization of enormous archaeological contexts like a whole ancient city has been a test bed to develop tools and methodologies in order to create and maintain accurate and fully real-time enabled 3D models. In the temporary exhibition, open until 30 September 2016, a multimedia installation based on "natural interaction" solutions was set up: thanks to Kinect and Leap-Motion sensors visitors can interact with virtual environments and objects, using gestures to experience a more engaging and intuitive experience.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Line and curve generation I.4.1 [Image processing and computer vision]: Digitization and Image Capture—I.6.0 [Simulation and modeling]: General—I.6.5 [Simulation and modeling]: Model Development—

1. Introduction

According to the last researches a Virtual Museum is

> "*...a digital entity that draws to the characteristics of a museum, in order to complement, enhancement or argument the museum experience through personalization, interactivity and richness of content. [...] A virtual museum can refer to the site, mobile or World Wide Web offerings of traditional museums or can be born digital content such as net art, virtual reality and digital art* [HHT*14, p.39]."

Given that, a common issue in the production of a Virtual Museum is in the lack of a clean work-flow able to connect real archaeological data, collected by experts in antiquity, and the deployment of the final installation. The cause of this situation is likelihood the absence of a project that keep in consideration from the very beginning a structured communication plan of the scientific discoveries and the lack of connection among the different research domains involved. Furthermore on one side the content of the archaeological record is often intended to offer only a description of the contexts with insufficient attention to the visual environment of the site. On the other side, digital archaeological records (3D point clouds from archaeological excavations, stratigraphic data etc..) require time consuming transformations and adaptations in order to make them usable in a virtual museum. A common example is a 3D acquisition where the optimization of the models is a key point to enable effective virtual museums and realistic and immersive experiences.

Figure 1: *Room of the exhibition with the installation running and the masks on the walls.*

On April 7th, 2016, the exhibition "3D Rome - Sarmizegetusa. Turn on the History" was inaugurated in the halls of the National Museum of Transylvanian History (MNIT) in Cluj, Romania (*see* Fig. 1). It was a co-production MNIT and CNR-ITABC (VHLab - Virtual Heritage Laboratory), in collaboration with various partners, including the Trajan Markets - Museo dei Fori Impe-

DOI: 10.2312/gch.20161386

Figure 2: *Real-time exploration of the excavation of the* Termae *(Domus Procuratoris).*

riali (Rome) and MCDR. In the exhibition the issues mentioned above were overcame by connecting museum objects with their original environment together with virtual reconstruction. this allowed to visitors to understand the archaeological sites in a easier and effective way. By means of the use of Exposition (defining and describing monument and artifacts to inform visitors and making them aware) and Narrative (providing information and interpretation about monuments and artifacts by arranging them in a sequence) communicative styles [FPF14], we boosted the visitors tour with an immersive experience. In the exhibition, the visitors, using their own bodies, can walk through the remains of the grandiose *Praetorium Procuratoris*, the *termae* being excavated (*see* Fig. 2), and the Great Temple (the largest temple of the entire Dacia province) with a first virtual re-constructive hypothesis in semi-transparent overlay. In addition to the Sarmizegetusa virtual scenarios, visitors can explore two contexts of Ancient Rome - the Forum of Augustus and the Temple of Peace - which ideally represent the formal origin and reference inspiration models of the monuments of the Roman provincial capital. Along the virtual tour, visitors can "pick" archaeological remains up by means of hand gestures and eventually "pass" the virtual object into a separate screen, where another visitor can manipulate it with simple hand gestures, always through natural interaction solutions. In this way, precious objects like the gilded bronze satyr or the *Gorgona*, the capital of the winged Pegasus and other jewels of the collections of the Museum of Cluj-Napoca, Museum of Deva and the Trajan Markets Museum can be further inspected in their original context of discovery. More, some original objects that visitor can find in the application were set up in the exhibition room in order to make a direct connection between real and digital artifacts. The original archaeological finds were placed using an innovative concept behind plaster masks that imitate the ones from Pompeii.

The case of Virtual Sarmizegetusa in the last 3 years has been a perfect test bed for a wide experimentation of acquisition methodologies and techniques. A strong focus has been given to the survey approach, trying to go beyond the traditional digitalization concept and looking for a "digital replica" where geometries, colors, structure of the light, photos and equirectangular panoramas are collected at very high detail in order to enable a realistic VR experience. Finally, since that the ancient city is located in the Retezat National Park, several samples of vegetation elements were collected in order to recreate the current natural environment (trees, bushes, grass). The Virtual Sarmizegetusa Project is part of a wider series of scientific actions on the ancient site of Sarmizegetusa that includes excavations (MNIT and UBB, MCDR, UNIEXE, UHEI, UVIE) and geophysics analysis (MNIT and CNR-ITABC).

2. The case of Colonia Dacica Sarmizegetusa

Colonia Dacica Sarmizegetusa was the first and only colony of veterans of the Roman province of Dacia. It was created immediately after the conquest of Dacia by Trajan in the years 108-110 A.D. and until Marcus Aurelius remained the only colony of the province. In the center of the site it has been identified and researched the Forum Vetus. Soldiers of Legio IIII Flavia Felix built the forum wooden construction phase and immediately afterwards the stone phase. They also participated in other assemblies colony construction: the city wall, Horrea near to Praetorium Procuratoris. Colonia Dacica Sarmizegetusa have a quasi-square shape inside the walls to start

measuring 22.5 ha, and 33 ha and ha 60-70 Extra Muros. Throughout first century AD Sarmizegetusa was the main cultural center of the province, which contributed to the embellishment of numerous evergetes. Under Alexander Severus got the epithet of metropolis city, which is a testament to his prosperity. It is the only city in the western Roman Empire receiving this epithet. The reconstruction of the stone amphitheater under Antoninus Pius, *Forum Vetus* reconstruction in marble after the Marcomanic wars demonstrates also a flourishing city. Sarmizegetusa was also *Concilium Trium Daciarum* headquarters, the altar of Rome and Augustus [Cio07].

3. Virtual Sarmizegetusa Project: the digital acquisition

The creation of the Virtual Sarmizegetusa installation allows different technologies and methodologies to be tested simultaneously. Tasks like digital acquisition on the field, inside museum collections and further optimizations of virtual environments and assets stimulated new issues and promoted new solutions, both from a technological point of view (creation of new software) and methodological one (fitting scientific documentation needs with current technologies).

3.1. Optimization of models and multi-resolution for virtual environments

When dealing with the representation and interactive visualization of large environments, a common approach consists in 3D assets segmentation and creation of hierarchical out-of-core organizations [BGB*05] [**?**] [**?**] for multi-resolution. When properly organized, such structures allow fully explorable and theoretically resolution *"limitless"* environments. Creating a gaming experience for a Virtual Museum on the subject of a great capital of ancient world (33 ha) fits exactly this scenario. All the models have been optimized (geometries and textures) using multi-resolution approach and according to a given spatial and hierarchical structure, designed on top of the blueprint of the ancient city. The 3D models have been divided into reality based models (unique objects from photogrammetry) and sample-based models (models of type object reused as instanced assets with small parametric-driven differences) like in the case of trees, rocks, sheafs etc.. Optimizations have been performed in computer graphic software Blender 3D with manual tools and ad-hoc scripts (see Blender Landscape) and using new dissemination on-line Front-End, applied to the gaming experience. In order to deploy a smooth workflow and methodology during ingestion phases from 3D modeled objects and environments to the real-time visualization framework, a set of open-source desktop tools has been developed. Targeting this context, real-time object painting and scene dressing tools, alongside specific optimization tools have been implemented with drag&drop approach. The latter led to small mini-processing units (*"droplets"*) that combined with preview tools, allowed fast ingestion pipeline even under strong time constraints. A similar approach was used to process and publish on-line a set of 3D objects and archaeological sites related to the exhibit: we employed a new Front-End, *Aton* (`http://osiris.itabc.cnr.it/scenebaker/index.php/projects/aton/`) with *out-of-core* multi-resolution support. The Front-End targets all modern browsers supporting WebGL technology and also mobile browsers, including multi-touch features. The latter is a crucial requirement in this case to connect mobile fruition with the on-site gaming experience, thus extending it to smartphones and tablets. Especially appealing in this context is the capability of the Front-End to present rich and spatialized multimedia annotations (images, audio, videos) that well fit presentation requirements, such as multi-language audio and text (English and Romanian) as well as reference photos of original items in the museum (see Figure 3).

4. Integration of virtual and real Museum: the exhibition

The exhibition concept is designed like a 3D video game where the "time traveler" is a treasure hunter. For a better understating of the exhibition it was set a "intro" room were are presented some reconstructions drawings of the most important monuments from Colonia Dacica Sarmizegetusa archaeological site, some of them being present also in the 3D application. The reconstruction drawings talk about Forum Vetus with its construction phases (wooden, Trajanic stone phase, and Antonin middle and late phase in which the city is marbleized), Forum Novum with its Capitoline Temple, the amphitheater with its phases of construction, the amphitheater baths and also a model of a roman home researched at Sarmizegetusa site. The uniqueness of the exhibition derives from the fact that restored digital 3D monuments and artifacts are combined in the main room with the presentation of real artifacts, discovered during excavations at Colonia Dacica Sarmizegetusa site by Romanian archaeologists. Some of them are located in the exhibition hall inside illuminated niches refined and it can be admired through the mouth of four masks, replicas of the originals from Pompeii. The masks were manually built in plaster using "*ronde-bosse*" technique after some Greek theater type masks that were made of marble or terracotta that decorated the painted walls of the roman houses. Behind the masks the walls are decorated with beautiful posters that imitate the frescoes from Pompeii. The bronze pieces from the archaeological site of Sarmizegetusa are hidden behind the wall and near the masks is set up a QR code that offers the visitor to *"take"* home the artifact by visiting a WebGL page with the 3D model and to interact with it using full multi-touch manipulation (pinch to zoom, rotate and pan) using the previously introduced Front-End (*see* Fig. 4). The interactive visualization allows also to read more information about the real artifact. The rest of the room was populated also with other real artifacts as a marble capital and votive altar, and also a *hypocaustum* brick. In the corners of the room were placed two plaster copies of Niobides statutes from Rome in order to illustrate the connection between the two roman capitals from the 3D application. On the front wall was built the screen and the monitors for the digital part of the exhibition.

5. Conclusions and future works

Expected results of this procedure are rich connections between the site, the local museum and artifacts collection. Some typical contexts for the roman times like *domus*, city gates, furnitures that are present in the museum has been provisioned to the visitors in order to enable a deeper understanding of the ancient town. A first result of our research activities is the digitization and documentation of an unique archaeological site and the creation of new ways to communicate and perceive the cultural heritage treasure of an emerging

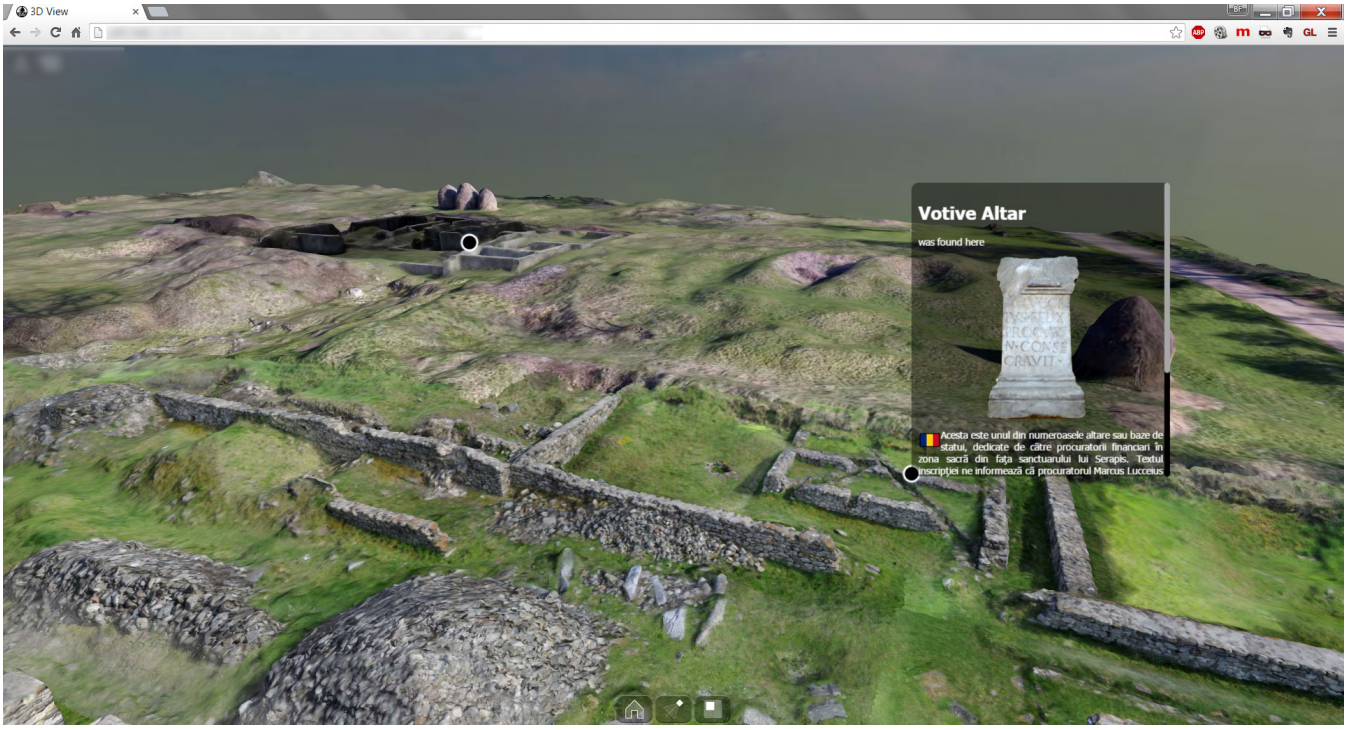

Figure 3: *Interactive online dissemination of two multi-resolution archaeological sites with rich multimedia annotations, including two languages (English and Romanian) used for audio-descriptions of findings.*

Figure 4: *Bronze piece of the Gorgona behind the Mask and the visualization of the corresponding 3D online model.*

European touristic country like Romania. New technologies like UAV systems, Dense Image Matching, Natural Interaction, WebGL dissemination and Virtual Reality were used in order to empower at the same time both research and preservation through high resolution 3D models and, on the other hand, the dissemination and provisioning of new tourist attractions. Within two years there will be further exposure with the next step of the project, in which the current city will be fully explorable. We would like to achieve a virtual reconstruction of the city and the most outstanding buildings that have represented the core of the roman life during the 2nd and 3rd century and arrange the digitally restored objects inside them. The final goal of the virtual reconstruction is the development of a series of on-site multimedia connected applications to improve the quality of the visit, disseminate information in a more effective way and allow a better understanding of the archaeological site and art objects to be experienced. Indeed the museums domain is rapidly changing [Pes14, p. 132-134]: Sarmizegetusa will be a perfect cultural district to test and deploy this kind of next generation virtual museums. Museums need in fact to offer constantly new, entertaining and scientifically validated exhibits, providing technological solutions with coherent visual information and above all stories, interaction and comprehensible relations between objects displayed and their contexts.

References

[BGB*05] BORGEAT L., GODIN G., BLAIS F., MASSICOTTE P., LAHANIER C.: Gold: interactive display of huge colored and textured models. *ACM Transactions on Graphics (TOG)-Proceedings of ACM SIGGRAPH 2005 24*, 3 (2005), 869–877. 3

[Cio07] CIONGRADI C.: *Grabmonument und sozialer Status in Oberdakien*. Mega-Verlag, 2007. 3

[FPF14] FERDANI D., PAGANO A., FAROUK M.: *Terminology, Definitions and Types for Virtual Museums*. Deliverable report 2.1c, CNR, CULTNAT, 2014. 2

[HHT*14] HAZAN S., HERMON S., TURRA R., PEDRAZZI G., FRANCHI M., WALLERGARD M.: *Theory Design*. Deliverable Report 3.1, CREF-Cyl, 2014. URL: http://www.v-must.net/sites/default/files/D3.1_update.pdf. 1

[Pes14] PESCARIN S.: Museums and virtual museums in europe: reaching expectations. *SCIRES-IT-SCIentific RESearch and Information Technology 4*, 1 (2014), 131–140. 4