BRIEF OVERVIEW OF EXAMPLES OF VR PROJECTS

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In recent years 3D technologies have yielded a unique opportunity for archaeologists to present their archaeological investigations in this form. Since archaeological record is woven of images, texts, measurements and drawings, 3D presentation has turned out to be an ideal medium for keeping, analysing and presenting archaeological contents.

Contemporary software solutions create three-dimensional models of objects and present them in different ways, with a varying degree of realism and interactivity. We are now able to recreate and visualise historical structures and discuss them in both professional and the popular contexts.

The typical characteristic of archaeological finds and features is their fragmentation and different level of preservation. For the purpose of modelling, it is necessary to obtain the 'missing data' in alternative ways. There are several possibilities for this procedure (Ferdani, Bianchi 2014):

- Reconstruction by "analogy": The reconstruction is based on analogy with a well-known and recognizable theoretical model. Despite having only a part of an object, the reconstruction can be carried out by referring to a widespread standard.
- Reconstruction by "comparisons": The reconstruction is not based on a theoretical approach, but on direct comparisons with extant remains in the local area.
- Reconstruction by "deduction": although some buildings or architectural elements are incomplete, their complete appearance can be deduced by referring to the formal characteristics of the buildings, or to repeated patterns.
- Reconstruction by "hypothesis": This is the most complex process. Hypotheses are based on conjectures or the archaeological evidence.

Below are some examples of 3D modelling projects, their goals and methods, which are highly inspiring.

Project www.virtuelnavinca.com

VirtuelnaVinca is a result of the collaborative work of N. Stojanović and N.N. Tasić on the presentation and reconstruction of the Neolithic figurines recovered in archaeological excavations at the site of Vinča over the period 1998-2009. The example of VR integrated in a 2D format is available on the website that presents these valuable artefacts in a new and distinctive way.

3D recording of the figurines was conducted using photogrammetry and the 3DSOM software. The reconstructions are artistic, but based on the principles and concepts of archaeological reconstruction. The use of an internet website as the medium provided endless possibilities for displaying the ideas that the authors of these reconstructions came up with during their research. One of the key advantages was the possibility to show different versions of the reconstruction of the same figurine. The best example for this is Figurine C149 for which different reconstructions were plausible. Given that the upper part of the figurine torso and the neck are missing, it was not possible to, with some level of confidence, determine which figurine type this one belonged to and how the head could have been modelled. Thus N. Stojanović presents three versions of the reconstruction; one of them even shows a two-headed figurine, which is the type that indeed occurs at Vinča but is not particularly common.

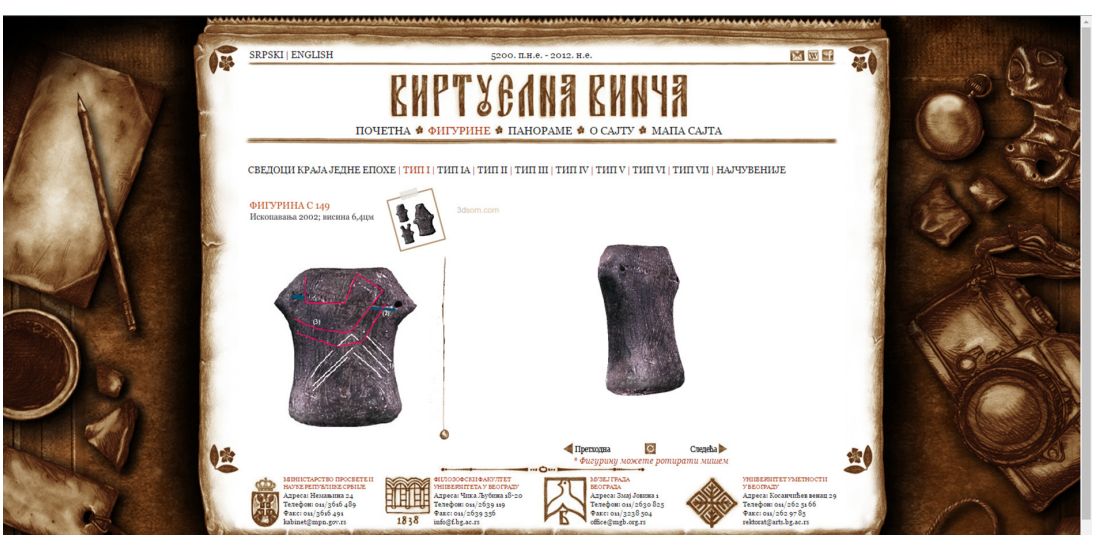

Figure 7. Page with applied 3D models of the Vinča culture figurines.

Çatalhöyük

The project virtually reproduced the entire archaeological process of excavation using 3D technologies (laser scanners, photogrammetry, computer vision, image modelling) on-site, and also created 3D Virtual Reality of the deposits of Çatalhöyük as they are excavated (in the laboratory, through tele-immersion). The final goal of this project is to create a virtual collaborative space where it is possible to make the excavation process completely sharable (Forte et al. 2012).

Figure 8. Examples of contemporary level of 3D reconstruction from Çatalhöyük (ArtasMedia).

The process goes through the following phases:

1. Digital recording by laser scanning (phase shift) and image modelling (DSLR cameras and specific software such as Photoscan). Data acquisition of any single phase of excavation and layer. Time sessions of 15 minutes.
2. Digital recording of artefacts by total station.
3. Post-processing of all 3D data collected on-site: decimation, interpolation, meshing (software Meshlab, Photoscan).
4. Spatial integration of all data (layers, stratigraphy, models) in one viewer (Meshlab, Vrui Toolkit).
5. Implementation of data and models for the Tele-immersive system (Vrui Toolkit).

Uruk

The Uruk Visualisation Project was performed by the expert from Das Deutsches Archäologisches Institut, Berlin according to the highest standards in authenticity and the quality of applied technologies (Hageneuer 2014) . This project had three distinct goals: to enable discussion on, and the scientific work with, the architectural remains by evaluating the archived material and through development of reconstructions and visualisations, and to use the visualisations in the Visitors Centre at the site of Uruk.

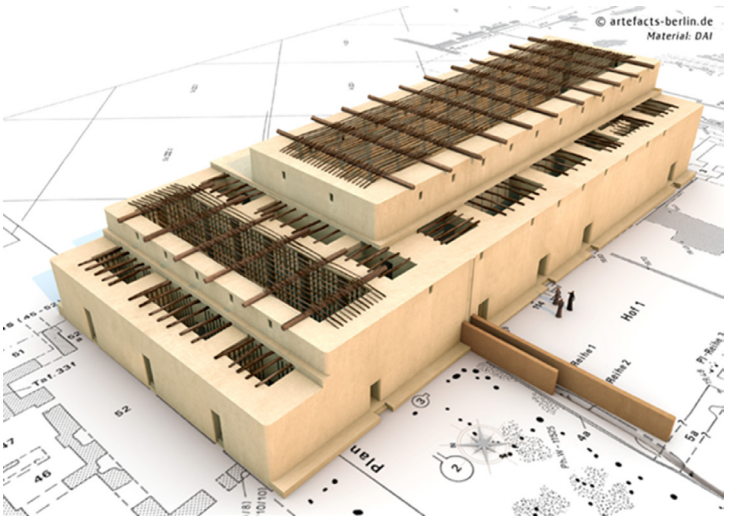

Figure 9. 3D interpretation of a building from Uruk (copyright DAI, Berlin).

Etruscanning 3D project

The communication of Etruscan graves and collections in museums through innovative VR systems and multimedia **(**Hupperetz et al. 2012). The public has the possibility to explore the virtual tomb, to get acquainted with the artefacts, to listen to the impersonation of prestigious Etruscan persons to whom these objects were dedicated. We can hear the princess and a warrior as if they were immersed in our world observed from their point of view as the Etruscans. So, they speak as rulers of an Etruscan city-state, with

Figure 10. 3D model of Etruscan sarcophagus (copyright sarcofagodeglisposi).

aristocratic authority, but they welcome the visitors to the exhibition, just as they had welcomed so many people in their lifetime. Their point of view is that they indeed enjoy the afterlife; they keep on living so many years later, through the scientific research, the publications, museums and exhibitions. They look upon us and how we deal with their culture, not giving away the secrets that we still have not unravelled. Important message disseminated by this project is that the role of heritage should be regarded as crucial; the project reveals how much Etruscan heritage has contributed to the society of today.

Virtual reconstruction of Belgrade of the 15th century

The city of Belgrade became the Serbian capital in 1403 when Stefan, the then ruler of Serbia, moved his palace to the town overlooking the confluence of the Sava and the Danube rivers.

With respect to the earliest attempts at creating 3D reconstructions in Serbia, we must go back in time, to the year 2004 and the period before the most recent financial crisis. This is when the Innovation Centre of the Faculty of Philosophy (the Centre for Digital Archaeology of the Faculty of Philosophy) received an offer to produce a reconstruction of the Belgrade Fortress from the time of King Stefan of the 15th century, and for the purpose of the "European Heritage Days" manifestation. As M. Forte states in his 2010 paper, the early attempts at virtual reconstruction were not funded from the sources intended for scientific research, but from the sources reserved for sponsoring manifestations whose main aim was popularisation of politicians and their political parties. Still, given that in this kind of situation one cannot simply pick an investor, the Centre for Digital Archaeology accepted the challenge and, in less than four months, designed an interactive stereoscopic presentation of the reconstruction of the Upper Town of medieval Belgrade.

Specialists from a range of different disciplines contributed to the project. The work was completed with great success and in an incredibly short period of time by: M. Popović, professional consultant, V. Jevremović, author of the virtual environment, D. Tasić, an architect, N.N. Tasić, coordinator, and the team of programmers, 3D modellers and texture artists. The parts of the walls and the fortress that have not been preserved were reconstructed following the instructions of medievalist

M. Popović who has, for decades, studied this particular period and the region, with special focus on the Belgrade Fortress. The area of the Upper Town was scanned in the smallest of detail and the data were used to create a 3D model of the terrain. Then the existing plans of the layout and the preserved walls and towers were imported. On the basis of analogies, relevant written sources and the available engravings, the appearance and the architectural elements of the Upper Town were reconstructed.

Thanks to the GUI platform, developed at the Centre for Digital Archaeology (by V. Jevremović), the finished product facilitated interaction with the reconstruction, that is, it was possible to walk around the virtually reconstructed 15th century Belgrade by moving the computer mouse. The towers, walkways and the king's Magna Sala Audientiae

Figure 11 A. Belgrade of the 15th century, example, and audience at the premiere (copyright CDA).

Figure 11 B. Felix Romuliana, Gamzigrad, examples of 3D reconstruction (copyrignt CDA).

were reconstructed in full detail. The use of 3D projectors and the appropriate polarising eye-glasses enabled the audience to experience the virtual tour in 3D space. As with the other virtual reconstructions created at the time, human figures are missing since the time available for the completion of the project was too short to allow preparations of the animations.

What remains unclear and what still puzzles both the authors of the project and the audience is the fact that, the reconstruction was on display during the "European Heritage Days" manifestation and for a short period after it, but the opportunity was missed to include the virtual reconstruction into the regular Belgrade Fortress tourist offer. There could be many reasons for this, most of them of political background, but some of them also lie in the absence, at the time and in the particular social environment, of understanding on the part of stakeholders and decision makers of the importance of virtual reconstructions.

Virtual reconstruction of Felix Romuliana

Felix Romuliana is the name of the ancient Roman complex of palaces and temples. The systematic archaeological excavations conducted since 1953 revealed that the site was conceived and built by one of the Tetrarchs, Emperor Galerius, the adopted son and son-in-law of the Emperor Diocletian. The main area of the site covers 40,000 m^2.

Figure 12. Felix Romuliana, Gamzigrad, an example of reconstructed Roman architecture (copyrignt CDA).

The virtual reconstruction was created in 2006/2007 as a result of the collaboration between the Faculty of Philosophy in Belgrade, the Institute of Archaeology in Belgrade and the Museum of Zaječar. The reconstruction was based on the data collected

in thorough excavations performed over 15 archaeological campaigns. The terrain configuration was recorded using the EDM which enabled the production of the digital terrain model. Unlike the previous "analogue" reconstructions of this Roman royal city, this one has taken into account the properties of the terrain and has shown that the essential approach to the reconstruction must be different from that taken in previous reconstruction attempts. The analysis of the position of structures such as temples, peristyles, palace etc. indicated that the building complex was, architectural, highly adapted to the contours of the terrain at this location. Understanding and presenting the placement of various structures at Felix Romuliana opened up a possibility to put to rest long-standing disputes in archaeological literature by the scholars whohave been unable to grasp spatial relationships between the buildings, the walls and the gates of the complex.

3D-Icons Project

The aim of the EU funded project 3D-Icons, coordinated by Università degli Studi di Napoli L'Orientale was to supply Europeana[1] with 3D items such as archaeological sites, architecture, monuments, artefacts and UNESCO World Heritage assets and to ensure further:

- establishing a complete pipeline for the production of 3D replicas of archaeological monuments and historic buildings which covers all technical, legal and organizational aspects;
- creating 3D models and a range of other materials (images, texts and videos) of a series of internationally important monuments and buildings;

contributing content to Europeana using the CARARE[2] aggregation service. (http://3dicons-project.eu/eng/About)

For adequate and purposeful metadata creation authors claim that specific skill is required as the complex articulation of data requires high level of expertise in the archaeological/historical field. In this time-consuming process collecting the information required for acquiring adequate, descriptive metadata is often requiring more time than allowed by the project duration. In this project, 3D data collection was conceived as an image-based system comprising of: Small textured objects; Triangulation-based system – small non-textured objects; ToF system – large objects (buildings); SfM (SourceFilmmaker animations). The only controllable input are images and authors rightfully draw attention to this fact. They see possible imaging problems in following: Image blurring due to movement during shooting, wrong focusing, limited depth of field. Lighting/dynamic range – backlights/mixed colour temp, light spots, highlights. Confusing scene elements –- painted walls/mosaics, high contrast elements around the subject.

1 Europeana is the online portal for European culture dissemination. Its mission is to collect and disseminate Europe's cultural heritage and make it easier for people to use.

2 CARARE's goal was to harvest content relating to archaeology and architecture from providers across Europe and to provide it to Europeana.

- Image acquiring:
- The Higher Aperture = The Higher amount of Tie Points in Photoscan (f11 and higher)
- Possible use of HDR imaging to gain more details and better resolution
- Usage of Masks and monochromatic backgrounds is recommended

Archaeological 3D Modelling proposed by 3D-icons

Archaeological 3D modelling is not just a simple cognitive tool to reproduce aspects of the past; it is also a methodology of recording of all the archaeological data in a much more complete way than the traditional photography and drawing. It can be also regarded as an instrument of interpretation for the researchers who are involved in theoretical reconstruction of the past. Archaeological 3D modelling is essentially a re-creation and re-fitting of architecture and objects within reconstructed landscapes by digital means, based upon the current state of the salvaged monuments integrated with the data coming from historical and archaeological research, and using software for developing 3D models. The 3D reconstruction was carried out in ArchiCAD. Visualisations presented are simple mass studies, placed on a terrain created by software with schematically designated basic topographic characteristics. The details of architecture have not yet been elaborated in details – software pre-set basic textures were used (rough irregular stone, unburnt bricks, clay), and window and door openings have been left without any filler.

The following basic stages of the 3D reconstruction process of archaeological objects should be followed:

1) Collection of archaeological and architectural information – site layout, site photographs, pictures of the sites' surroundings from Google Earth, photographs and plans of architecturally similar and chronologically contemporary sites, original iconographical sources (representations of structures and their construction details), architectural-ethnographical parallels (e.g. photographs of single farm houses and their remains), examples of some of already existing 3D reconstructions of architectural structures from the respective period.
2) Introduction to the architect of the site of the sources and basic facts on Minoan archaeology and architecture;
3) Analysis of the sources and preparation of the basic concept of the reconstruction;
4) Creation of the 3D reconstruction (by the architect/3D modelling expert, with the assistance from archaeologists) (Alusik & Sovarova 2015, 439).