

4D investigation of Digital Heritage

An interactive application for the auxiliary fortress of Carnuntum

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Abstract— Innovative methods (e.g. geophysical prospection, remote sensing prospections, 3D modeling and visualization) adapted to Cultural Heritage and Archaeology open a wide field of research which needs appropriate techniques, skills and workflows. However, Virtual Archaeology (VA) must be understood not only as a passive instrument for visualizing the data and results but rather as a digital tool that provides an interactive four dimensional framework where the user is able to visualize, explore, analyze and evaluate both raw-data and 3D reconstructions. In this paper we would like to present a new developed interactive application called Arch4DInspector developed by the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI ArchPro).

Index Terms— interactive application, Roman Auxiliary Fortress, Carnuntum, Digital Heritage, Virtual Archaeology, scientific transparency, dissemination, preservation, re-usability

I. INTRODUCTION

Due to the novel technologies applied to Cultural Heritage and the necessity of preserving resulting datasets for future generations, an innovative tool has to be developed. Typically archaeological datasets consist nowadays of many different sources combining various archaeological sciences and disciplines (e.g. remote sensing, geophysical prospection, excavation data, sampling, historical data). For primary combination of these datasets an Archaeological Information System (AIS) [1, 2, 3, 4] based upon a Geographical Information System (GIS) is crucial. Within AIS several tools have to be embedded first to store efficiently the data and second to interpret it. Whereas comparability and fusion of datasets is gained in implementing GIS within AIS quantitative and qualitative spatio-temporal analysis has to be made through specific tools and 3d-viewers. These have to be developed and created for different types of archaeological research questions and visualize existing datasets and archaeological interpretation of archaeological evidence.

To ensure such an endeavor all the available data must be taken into account, processed, analyzed and combined through appropriate methods and skills. The final output is an interactive tool that allows not only to visualize but also to explore in detail both original data-sets and virtual reconstructions. The main advantage of that is the chance to

generate a digital environment in which results can be analyzed in detail both in space and time whereas new hypothesis and interpretations are offered and can be scientifically discussed. The recently developed tool Arch4DInspector illustrates the necessity of this approach.

The Roman town of Carnuntum is a high-level archaeological site being the capital of the Roman province Pannonia Superior. This long term case study hosted by the LBI ArchPro is the investigation of the archaeological landscape of the Roman town of Carnuntum and its surrounding area close to Vienna (Austria). Through the last years high resolution data from Ground Penetrating Radar (GPR) surveys and magnetic prospection resulting also in the detection of a Roman gladiatorial school [5] were carried out. The results represent the temporal and spatial development of a whole Roman town accompanied also by historical data sources. As a case study within this enormous dataset the analysis and visualization of the revealed different phases of the auxiliary fortress northeast of the civil town of Carnuntum was chosen. This multi-phased auxiliary fortress seems perfectly suited for a first test of Arch4DInspector to visualize spatio-temporal correlations derived from various existing archaeological datasets.

II. MATERIALS AND METHODS

In this particular case, all the already digitalized and processed data-sets together with various 3D reconstructions were included within an interactive application (Arch4DInspector) that presents the Auxiliary Fortress of the Roman site of Carnuntum (Lower Austria). For this purpose datasets based upon the following sources were used:

- Archaeological excavation maps and reports [6].
- Non-invasive prospection methods results (GPR and Magnetic).
- Remote sensing prospection methods results (LIDAR and aerial photography).
- Contemporary Roman sources.
- Analogies.

All datasets were combined, analyzed and interpreted within an AIS based upon GIS resulting in a geodatabase. For the

visualization and further analysis of spatio-temporal correlation between documented features and structures (e.g. walls, buildings, barracks, roads, ramparts and ditches) Arch4DInspector was developed and tested.

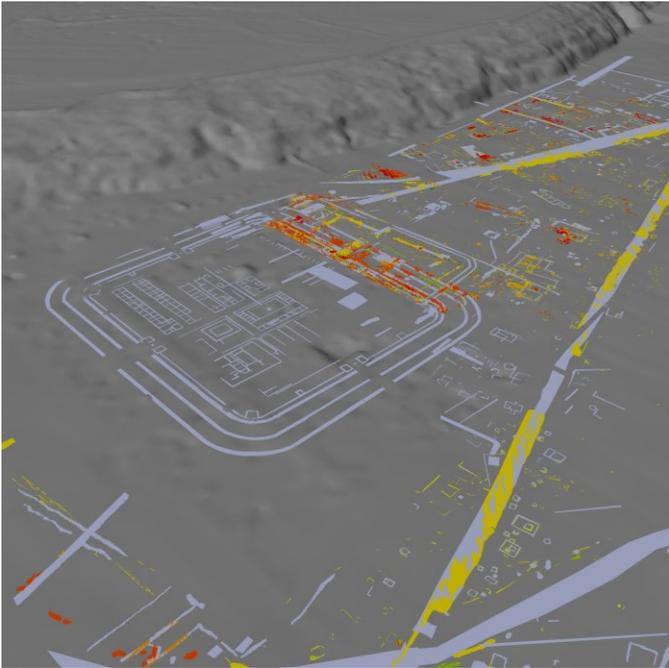


Fig. 1. Data-sets and DTM loaded in 3ds Max 2014(© LBI ArchPro, Torrejón).

For this purpose several software solutions have been tested and evaluated. In first place, all the data-sets were loaded along with a Digital Terrain Model (DTM) into a GIS Software (ArcMap 10.0 and ArcScene 10.0) from where they were imported into a 3D modelling software (3ds Max 2014) as 3D files (.wrl format). In this platform different sets of 2.5D and 3D interpretations are combined and analyzed (Fig. 1) serving as a basis for a first volumetric 3D reconstruction of the site and its phases. But, however, the DTM was primarily edited to erase traces of modern structures (e.g. roads, buildings, fields). Secondly, negative structures (basically ditches) around the fortress were created. At the same time, archaeological data (especially from GPR results) provides information about each surface level on the different phases. This DTM is then used as a surface where all the 3D models are placed. Once all the phases and areas are differentiated, every single building and feature is modeled within its period (Fig. 2).

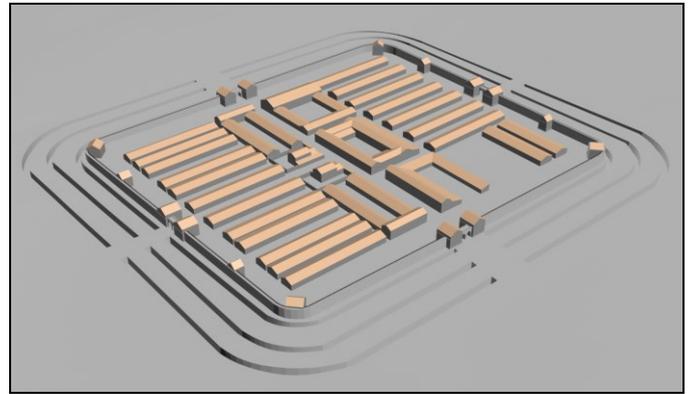


Fig. 2. Modeling process of phase II in 3ds Max 2014 (© LBI ArchPro, Torrejón).

After all the phases are plotted, digital tools also allow the creation of various models and variations. In this way, two approaches are carried out:

- On the one hand, different architectural and structural solutions are outlined regarding to the archaeological data itself and available analogies. These analogies are taken into consideration according to spatio-temporal and functional correspondences.
- On the other hand, diverse levels of detail [7] are delineated. Three levels are distinguished in this step. The first one would be a basic volumetric model only regarding to the size of the areas and structural units. The second one would be a more detailed version but still taking into consideration the archaeological results and finds that come from the available datasets. Finally, a more refined model is created adding some features that are not directly preserved in the archaeological record such as organic features or robbed out structures (which are still visible in the data). This lack of information is, however, filled by some external information mainly given by analogies and contemporary Roman sources.

Those 3D models can also be presented in several visual results. A grey-scale texturing would provide a basic depiction of the features paying more attention to the volumes and distribution. But moreover a level of accuracy scale is applied to the models (Fig. 3) to show the reliability of the reconstructions. Eventually, a more artistic texturing is used in order to get a more realistic appearance.

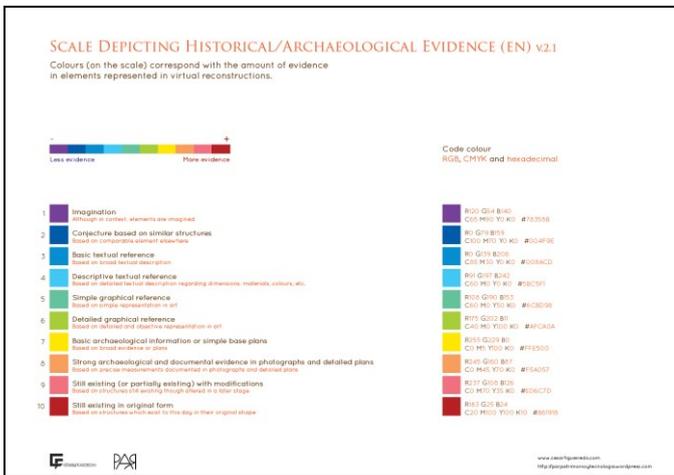


Fig. 3. Scale Depicting Historical/Archaeological Evidence proposed by P. Aparicio and C. Figueiredo (© Aparicio and Figueiredo). [8]

When all the modelling procedures are finished, 3D models are imported (as .obj format) into a real-time engine (Unity 5) where the digital framework is developed. For a better depiction of archaeological interpretations and reconstructions a simple but meaningful software called Arch4DInspector (Fig. 4) was developed. It basically allows the user to switch between all archaeological data used in the modeling process while observing a reconstructed 3d model on top. The interface consists of so-called data-buttons that allow the user to enable and disable different types of information which is transparently layered on top of each other, a slider for depicting the 3D model through time and a button that orbits the camera around the data and 3D objects for a better inspection.

Furthermore the generated application can be uploaded to the Internet to be open and freely used by the scientific community as well as the wide public.



Fig. 4. Layout of Arch4DInspector showing both interpretation results and 3D reconstruction (© LBI ArchPro, Torrejón).

III. RESULTS

The main output of this project has been a first prototype of an interactive application that shows a 3D reconstruction of a Roman Auxiliary Fortress in the Limes of Pannonia along with all the available data which has been previously combined and interpreted. It permits the user to visualize those data-sets as well as a chronological evolution of the site and several 3D reconstructions.

The main advantage of a 3D reconstruction is the possibility of visualizing the given interpretations and therefore to test and discuss them. During the process a feedback may occur and the interpretations are refined creating an iterative process (Fig. 5).

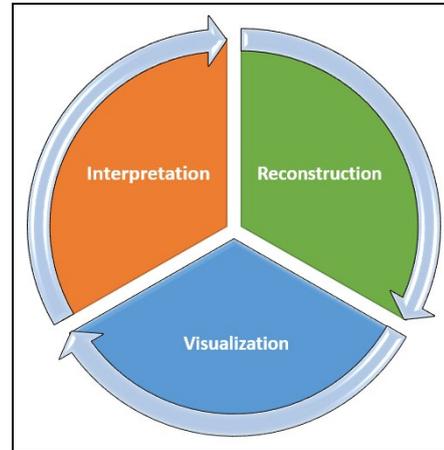


Fig. 5. Diagram of iterative process (© LBI ArchPro, Torrejón).

Through the use of this kind of tools, a great level of scientific transparency is ensured. The user can observe 3D models of a specific archaeological site accompanied by all the accessible scientific data and interpretations.

The developed application also provides the possibility of disseminating the results among the scientific community and the wide public. For that purpose digital and social media can be used and consequently an external feedback process can take place.

IV. DISCUSSION

Due to 3D reconstruction potentials (i.e. visually powerful, easily disseminated), it is crucial to assure the reliability and reproducibility of the results. To do so, it becomes imperative to follow certain rules given by such documents as the Principles of Seville [9] or The London Charter [10] which intend to be guidelines for Virtual Archaeology with specific respect on reconstructions. For the reproducible analysis and interpretation of archaeological data based upon a georeferenced AIS the definition of VA has to be extended further to visualization, exploration and simulation of archaeological data.

In order to keep a suitable level of reliability, 3D reconstructions must be accompanied on the sources that they are based as well as a frank level of accuracy of the models

(scientific transparency). For that purpose and as it was mentioned, a color-based scale can be used.

An additional characteristic of digital tools for Cultural Heritage is the re-usability of the generated models. Once they have been properly stored and managed, they are set to be reused in the future. This point is strongly linked to the fact that the given hypothesis is not a definitive conclusion of the research but merely a scientific based proposal as a starting point for further investigations.

V. CONCLUSION

In the digital world we can create situations which cannot be observed in the real world due to general perception of four dimensions. Other data is simply not accessible in a physical way because of the fact that they only exist within a digital frame (e.g. GPR results and their visualization). Thus, a digital environment is needed with the aim of visualizing different data-sets and creating connected contemporary units. Keeping in mind that archaeology in general is dealing with human caused and influenced changes in space and time this digital environment has to be based upon a georeferenced AIS providing various tools for closer analysis, visualization and simulation. Within this AIS not only different datasets are analyzed but also new datasets are generated in a virtual environment.

This kind of tools are certainly needed due to the inherent characteristics of archaeological remains. Although they have been traditionally presented as static features, they actually are, on the contrary, organic and changeable elements which have been altered along History by mankind and natural phenomena and must be understood and interpreted in this sense.

Even though we do not intend to generate a 3D model that replaces the original archaeological remains, it is important to point out that in this particular case the site itself currently is a residential area and cannot be visited anymore. Because of that, the main advantage of our method in this manner is that those remains are, firstly, not altered from its original state and, secondly, they become worldwide accessible.

Concerning the responsibility for Cultural Heritage turning also into Digital Heritage exploration, visualization, reconstruction and simulation of archaeological datasets representing four dimensions within a virtual environment are necessary. In this respect the definition of VA and its purpose has to be extended following the existing basic definitions covering therefore also the procedures and methods described.

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