INTRODUCTION TO VIRTUAL RECONSTRUCTIONS

Nenad N. Tasić (University of Belgrade)

The first decade of the third millennium brought much advancement in the realm of information technologies. Human knowledge is rapidly migrating into digital domains and virtual worlds. The most far reaching one is, rather unexpectedly, the affordability of handheld devices able to easily reproduce 3D contents. Fortunately, archaeology is capable of making the most out of it. Images, videos, drawings, graphs and, of course, texts are the main components of any archaeological field documentation, of every archaeological report, or every scientific archaeological contribution. At the same time, the attitude of archaeology as a science towards the broadest audience is also changing as the habits of public change. The affluence of information we are heavily bombarded with makes the audience more fastidious towards the contents they are to choose. Grand exhibitions, travelling events, richly printed exhibition catalogues that we have seen during the eighties and the nineties were, back then, quite an effective way to approach and reach consumers of cultural contents. Archaeology was regarded elitist and was treated accordingly for a long time. But not any longer, I am afraid. Contemporary archaeology has to compete in the market with many rivals that strive to occupy every available second of consumer's time, as well as every bit of his or her focus. However, the possibility to attract much-needed attention of general public is there, it is available, and we should do our best to make use of it for the purpose of popularization and dissemination of our studies in cultural heritage.

As we will probably agree, virtual reconstructions are, together with nicely illustrated web sites, so far one of the best ways to reach out to the general public and, by offering palatable scientific contents of different studies and interpretations in cultural heritage, entice it to become a regular user of heritage-related contents. Another apparent benefit of making virtual reconstructions is that, the very process of building

virtual reconstruction encourages experts in the field of cultural heritage to work interdisciplinary, in teams; to work harder on their interpretations; to try and overcome the problems of incomplete information; and present their views and results which could be used for further interpretations and other visualization purposes. However, this golden opportunity is taking on much slower pace than one would expect and would have hoped for.

To excavate and discover the material evidence in order to interpret the past is, and will always be the main aim for archaeologists. It is what they do. However, due to the nature of taphonomic processes and archaeologist's desire to understand them, to discover their nature and sequence, the very nature of archaeological excavation is the *educated* destruction of different parts of cultural (historical) heritage. This paradox innate to our discipline is unavoidable when we try to acquire more knowledge of history. Of course, we produce field documentation which consists of texts, drawings, photos, videos and, more recently, photogrammetric documentation and even 3D models. We discerningly preserve artefacts and ecofacts, and in accordance with the current theoretical and methodological practice. We try to regularly update our ways of recording, aiming for our field documentation to be as much objective, accurate and precise as possible, because future scientific communities will depend upon the 2D interpretation of a 3D structural dataset of the recorded heritage. Or as De Reu and Plets have nicely put:

> *"…Archaeology requires detailed, high resolution registration and documentation techniques to maximize opportunities for future reproduction of the structural dataset, especially when it comes down to remains from non-preserved structures such as soil-features and structures in organic material. These methods should be fast and accurate, easily accessible and manageable for contemporary and future communities and preferably to be stored in three-dimensional format than in two dimensional. Multidimensional recording and reproduction of destroyed structures could bridge the gap between in-situ and ex-situ preservation. Moreover, new methods should enhance the quality of the archived heritage in terms of better visualization and allowing a personal participation of the present and future data-viewers in the manipulation of the images of the excavated structures." (De Reu, Plets, et al. 2013, 1108-1009)*

An interesting estimation shows that, in the 1930s, roughly a billion photos were taken annually, while at present this number is closer to a trillion. (www.viewbug.com)

So, we are slowly embracing the idea that our field documentation should be as detailed as possible, 3D ready and by all means readable (as in "format/media" readable) to future generations of archaeologists and IT users.

Every day many gigabytes of data are being produced in order to replace excavated structures and contexts. Dozens and dozens of ditches, houses, burials, fireplaces, mosaics, arches, capitals, sculptures and other archaeological objects are finding their way to our hard discs and other data depots in the form of images, texts or some other sort of input involving series of zeros and ones.

But it is not only field documentation that has to be accessible and readable. Interpretations, analyses and different "documentation supplements" should be kept the same way too, so that our present and future colleagues can make use of them as well.

And as far as the volume of our field documentation is concerned, we are actually producing thousand times more photographs, videos and drawings than, for example, was the case eighty years ago. It is reasonable to assume that, since the introduction of photogrammetry in archaeology, the number of photographs taken at a typical excavation is much larger and is still to grow. We are also making steps to make the documentation 3D ready. With respect to readability, it is not only up to us which format will survive on a long term, but we could actually foresee the proper format which will be used ten, twenty of fifty years from now. For example, the fact that quarter of a century has passed since the introduction of JPEG file format could be a hint that, in the near future there will certainly be ways to read this format (TIFF was introduced in 2001; MPEG-1 in 1993; MPEG-2 in 1995; MPEG-4 almost twenty years ago in 1998). So, we should not worry much whether there will be converters available for those formats in 2049. Migrating the data to a new medium from an obsolete one is a different story altogether and will be discussed elsewhere.

Since the year 2007 and the advance of Android and iOS platforms for handheld devices, we have witnessed an enormous rise in the capacity of the audience to acquire very complex contents in a very simple manner. Largely owing to the dedicated television channels, complicated scientific contents are becoming less and less insurmountable for broader public. The general audience is now easily digesting different interpretations on e.g. Persian wars, black holes, jet engines, beekeeping, furniture making, etc. Handheld devices now go many steps further than traditional books thanks to the ability to enrich the content being read, that is, to "augment the content". These devices enable you to see different useful information, various explanations, linked videos, 3D models and other computer-friendly content.

Yet, my *ad hoc* research of available interactive heritage-related 3D content on leading app markets for Android, iOS and Microsoft platforms indicates a very wide discrepancy between, on one hand, the size of the target group for such contents and the way it is nowadays equipped with technology, and on the other, the pitiful numbers of downloads of apps connected with archaeology or heritage. What can virtual reconstructions of cultural heritage offer in order to attract the attention of discerning clientele consisting mostly of the population often labelled *Millennials* or *Digital natives*?

Most applications related to the topics of heritage presentation reached only 500 downloads in the Android market.

The research on the current degree of application of innovative technologies in heritage presentation and dissemination, based on the number of downloaded virtual reconstruction and augmented reality applications and the offered contents in the markets for handheld devices, has reached the conclusion that, in spite of the availability of technological solutions, there is no actual interest for such contents. An example for

this is the fact that the *3D Çatalhöyük* application was installed fewer than 50 times. So, who is to blame?

The analysis of funding sources for some of the most inspiring and most technologically advanced apps offered on play.google.com show that, most frequently, the support for the complex and costly *chaîne opératoire* necessary for building virtual reconstructions comes from municipal or regional authorities, or the EU. Since virtual reconstructions are expensive to make and often yield no profit, seldom do we find a profit-oriented institution as an investor in such an endeavour. The primary sources of funding are, as we all already know, state funds which are often very limited and certainly cannot bring us to our main objective, which is to incorporate 3D models and interpretations in the field documentation and digital publications.

The first apparent downside of the virtual reconstructions apps in the eyes of the youngest segment of our target group (the digital natives) is that, the majority of virtual reconstructions are static or presented in the form of a fly-trough video, with not much going on except for the camera moving over often outdated and budget-restrained reconstructions of archaeological sites and monuments. Interactivity is what is clearly lacking! Unfortunately for us, motion capture and animation of interactive characters is, costwise, far beyond our reach. And we lack the knowledge, too. And even if we were not, as exemplified by the recent project of the Museum of Nikola Tesla and the private enterprise Digital Mind, in which the persona of Nikola Tesla was animated up to the highest standards of gaming industry today and made interactive for watching in virtual reality technology, the interest is still far too little to make this kind of projects self-sustainable and able to return the invested money. Two months after the inclusion of this content in the display of the Nikola Tesla Museum, this endeavour has been seen by fewer than 300 visitors. Later in this manual we will discuss possible solutions to this problem.

What is Virtual Reconstruction?

Virtual reconstructions have become an item in archaeology only recently, in the course of the last decade, primarily thanks to the appearance and availability of fast hand-held devices. To have in the pocket state-of-the-art device which can render 3D graphics in HD effortlessly was the trigger for this, now rather widespread, phenomenon. When in 2003 the author of these lines, together with his IT team and a group of eager young archaeologists, started applying 3D graphics in archaeological field documentation at the site of Vinča near Belgrade, Serbia, there were not many similar attempts in this field. The CAA conferences of the early 2000s were just glimpsing and starting to recognize endless possibilities of the medium which will probably become the straw to which archaeology as a discipline will hang on to, in its struggle for survival and confirmation in the age of consumerism and easy, ready-made and well-portioned swallows of knowledge and wisdom offered from marketing experts of all sorts. However, archaeologists have immediately grasped the opportunity and started promoting their discipline by introducing state-of-the-art reconstructions of

the past, well-adapted to the needs of an individual immersed in the era of consumerism – by using the internet...

F. Stanko et al. say: "Since the '90s, when computer science was oriented to the creation of work tools and solutions for the archive and management of quantitative data, to the development of virtual models and to the dissemination of knowledge, it quickly changed into a true theoretical approach to the problems of archaeology. It is now, indeed, able to influence the interpretation procedures and to revolutionize the language and contents of the study of the past. This new evidence introduced in several branches of the theoretical debate new scientific themes. These days, digital archaeology is considered as a computer aided approach to cognitive archaeology. Archaeological computer science is devoted to the representation with computer applets of the cognitive procedures behind the interpretation of the archaeological data, and the more popular virtual archaeology (VA), is the analysis of the procedures of management and representation of the archaeological evidence through computer graphic 3D techniques." (Stanko, Battiato & Gallo 2012, 1–2).

Paul Reilly pointed out: "In combining the interpretation with the measured data, it is easy to see how the two categories of information relate to one another. At the same time, attention is redirected to unexplained features or anomalies which are left exposed." (Reilly 1991)

Reilly (1991) defined Virtual Archaeology (VA) as the use of digital reconstruction in archaeology. Recently, the development of new communicative approaches to archaeological contents through the use of interactive strategies has been added to the scope of research of VA. According to these authors the birth of VA is not simply caused by the proliferation of 3D modelling techniques in many fields of scientific knowledge, but also by the necessity to develop new systems for archiving the ever-growing amount of data and to create the best medium for communicating those data using a visual language. From this point of view, the application of 3D reconstructions, equipped with different available techniques, became the core area of study of VA in regard to the potential of cognitive interaction offered by a 3D model. In this way, virtualization could be used as a method for communicating knowledge, especially in situations when:

- archaeological areas are well preserved but not accessible
- the sites have not been preserved but are known through traditional field documentation
- the sites have been destroyed but are depicted in iconographical repertoires
- presenting contextualization in a progressive dimensional scale (object, context, site, landscape)
- building functional simulations for the purpose of experimental archaeology

In this way, 3D reconstruction should be based on in-depth analysis of all available archaeological, iconographical and architectural sources, and supported by functional architectural analysis of the building interior from the point of view of the access into, and movement inside, the building and the reconstructed purpose of individual rooms.

Every stage has its own sub-stages e.g.:

- the collection of images,
- image management,
- the establishment of sensor position and image orientation,
- extraction of the geometric detail describing the object,
- merging of the geometric, texture and semantic data

In combining the interpretation with the measured data, it is easy to see how the two categories of information relate to each other. At the same time, the attention is redirected to unexplained features or anomalies which are left exposed.

3D Modelling as a Cognitive Tool

Computer graphics typically applied to the reconstruction and visualization of several features forming a context at an archaeological site, result in the creation of a multidimensional models which include different features derived from the excavation process. This process is fundamental for all archaeologists and particularly to scholars of virtual archaeology, the goal of which is to fit the reconstruction of archaeological objects within adequate landscape from the past. Computer science has the primary role in this branch of cognitive archaeology, and 3D modelling is not considered to be an optional implement for the addition of aesthetic elements in reconstructions, but an indispensable tool for analysis and interpretation.

From one point of view, 3D computer graphics reached the same level as archaeology itself, acting as a virtual version of experimental archaeology, and characterized by the study of "practice supporting the theory". It aims to replicate the experiments, to test archaeological assumptions by applying them to known contexts, such as assumptions concerning site formation processes.

Some authors make a distinction between digital, virtual and cyber archaeology. According to Forte, the term 'digital archaeology' generally includes all computing applications in archaeology (Forte 2013). By using this general term, one cannot further specify numerous nuances and differentiations. His opinion is that, the terms "digital" and "virtual" should be used for different purposes: "digital" and "computing" are mainly and usually connected with computing processes, while the term "virtual" should be related to cyberspace, 3D model and cyber environment. "Virtual" is synonymous with reconstruction, reconstruction means 3D models, and 3D models represent a photo-realistic artificial visions of the past (Forte 2013: 2). Forte promotes yet another term – "cyber archaeology" – and describes how it relates to Virtual Archaeology: "In virtual archaeology, the visual attention is on the background of the application, in cyber archaeology on the foreground: interaction, enactment, narrative, and cultural presence generate the simulation (Forte 2013, 22).

Since we will never have enough of data to absolutely accurately reconstruct the past, in order to obtain as refined picture as possible and come up with relevant interpretation of the past, we should analyse and improve entire digital hermeneutic cycle, from the first to the last step.

Digital archaeology, Virtual archaeology or Cyber-archaeology

Virtual Archaeology	Cyber Archaeology
Visualization Process	Simulation Process
Basic interaction	Feedback, Behaviours, Embodiment
Passive Users	Content Providers
Models engagement	Users' Engagement
Individual Environments	Collaborative Environments
Desktop	Immersive
Analogue-to-Digital	Digital-to-Digital
Models	Enactment/interaction
Computer Renderings	Cyberspace
Individual users	Virtual Communities
Animations	Real Time
Flythrough	Serious Games

M. Forte is posing a question of perceiving the interpretation process of the past as a digital hermeneutic circle (Figure 1).

Figure 1. Digital hermeneutic circle (after Forte 2014).

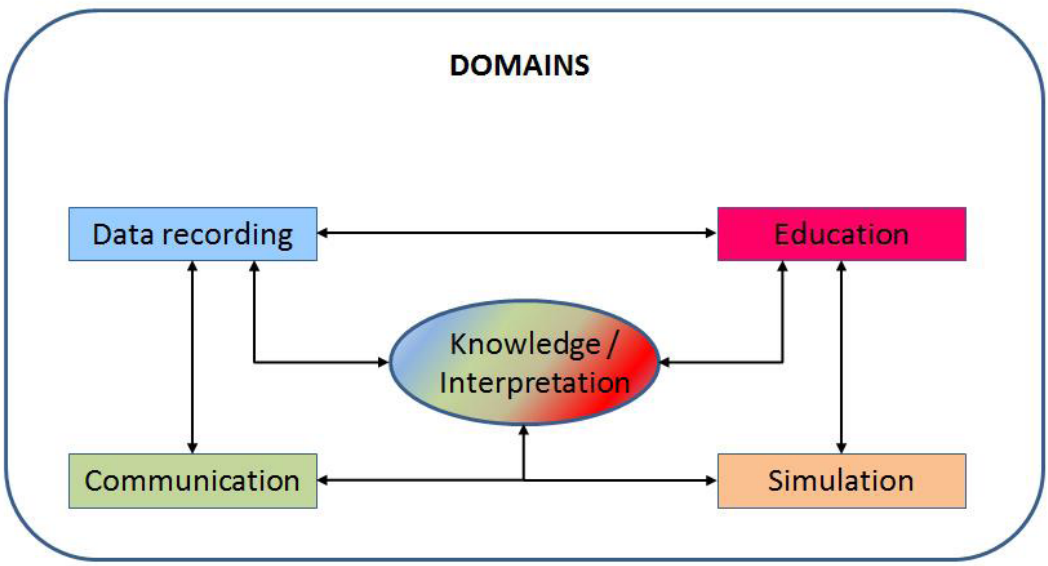

Figure 2. Domains of digital knowledge.

Virtual Archaeology workflow:

- Data capturing (analogue)
- Data processing (analogue)
- Digitalization from analogue sources (analogue-digital)
- Digital outcome: 3D static or pre-registered rendering

Cyber Archaeology workflow:

- Data capturing (digital)
- Data processing (digital)
- Digital input (from digital to digital)
- Digital outcome: virtual reality and interactive environments (enactive process)

One of the key problems in archaeology is that the flow of data from the fieldwork to the publication, communication and transmission is unbalanced: no matter if data are digital or not, a low percentage of them is used and distributed.

In his 2010 article, Forte has named this period the "wow era" because the excitement about the production of models was in many cases much bigger than the accompanying scientific and cultural discussion (Forte 2010).

The phase of data collecting, data-entry (bottom-up) is mostly 2D and analogue, while the data interpretation/reconstruction (top-down) is 3D and digital. The phase of data collection-data recording should be totally integrated into the simulation-reconstruction process; if we separate the two domains (bottom-up/recording, top-down /reconstruction/interpretation), we lose information and the capacity to compare and to validate data workflow in the virtual environment (Forte 2010).

Interactive cognitive experiences of 3D computer graphics can be characterized within two groups: passive and active. The first case refers mainly to the applications related to research and study, where the primary need is of documentary type, such as in archaeological excavations or in monitoring of the degradation. In the second case, interaction with the virtually recreated reality is further exploited in the enhancement of archaeological heritage through the creation of a virtual museum, accessible through digital media or on the web, intended both as a virtual version of a proper museum and as a closer study of an archaeological site.

The reconstruction process should present the sources and the thinking process that led to the choice of one reconstruction hypothesis over others; this, in fact, is the only way in which the research community can assess the scientific value and the reliability of a 3D model (Alusik & Sovarova 2015).

Well, there are good reconstructions and there are bad ones in both worlds. We should not deceive ourselves with the notion that inappropriate reconstruction is a speciality of the virtual world. There are numerous examples, both positive and negative. But there are also examples that are difficult to judge. Here I have in mind the reconstructions (both virtual and real) that reinstate (re-interpret) the appearance of a cultural monument, even though there are no sufficient supporting elements, and, moreover, the reconstructions themselves are not in any clear way detached from the monument. There are, on the other hand, projects, some even funded by the EU, that, although based on the research carried out in compliance to the recommendations, during the course of materialisation do not pay enough attention to the display of original (authentic) elements and their differentiation from the reconstructed components (e.g. medieval town of Golubac).

It is not before the 1970's that our researchers developed an interest in Golubac on the Danube, eastern Serbia. The interest was sparked by the construction of the hydro-plant "Đerdap I" because the project secured funding for archaeological research in the area. It was determined that the town's layout was adapted to the configuration of the terrain and that it comprises nine towers linked by walls, and the enclosed palace. The onset of the use of firearms in the 15th century left its mark on the fortress – the towers were modified fittingly and a new, cannon tower was erected. Although neither the exact timing of the construction of the town nor the architects are known, some researchers are of an opinion that Golubac resembles Serbian fortresses of the 13th and 14th century, and that it most likely represents a Serbian edifice from the time of King Dragutin (Milenković, http://www.tvrdjavagolubackigrad.rs).

Figure 3. Fortress in Golubac, Serbia.

Although there are clear rules, which we shall see further in this book, I myself am not sure that I would enjoy the view of a fortress in which most of the reconstructed walls, towers, curtain walls and roofs were of different colours (or built using different materials) that are intended to clarify to the observer the relationship between the original and the reconstructed segments. In order to satisfy the needs of the spectacle-seeking audience but, at the same time, respect the rules of the conservation, it is possible to use VR and offer the audience a view of the original created in the 3D realm. This would ensure an objective approach.