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VIRTUAL RECONSTRUCTIONS AND COMPUTER VISUALISATIONS IN ARCHAEOLOGICAL PRACTICE

CONPRA Series, Vol. IV

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Content

CONPRA PROJECT PUBLICATIONS AND THE PRACTICE OF PREVENTIVE ARCHAEOLOGY

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Preventive archaeology, in some countries also known as development-led archaeology, nowadays accounts for more than 90% of the archaeological work across Europe. In almost all European countries preventive archaeology is clearly the result of the implementation of the La Valletta Convention (1992) on the protection of archaeological heritage.

It is safe to say that, since then, the number of archaeological projects increased by 500% to 1,000%. Such an increase would not have been possible without radical changes in a number of factors that rule preventive archaeology, its concepts and practices: new legislation, introduction of preventive archaeology into spatial planning processes, a new financial principle (polluter – payer), new (digital) technologies for data retrieval and recording in field-based projects and, last but not least, a substantial increase in the number of active professional archaeologists.

With the emergence of preventive archaeology and its present dominance in the disciplinary practice,[1] the divide between academic and preventive archaeology became even more accentuated, and raised numerous discussions about the unity of the archaeological discipline and its future. While these two strands do not, and will not, differ in terms of the scientific methods and tools implemented in their research, they indeed differ in the reasons for undertaking archaeological research, and in their business and organisational contexts. Whilst these differences did not have such an influence on the nature of

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1   For more on concepts and development of preventive archaeology in the last two decades, see Bozóki-Ernyey Katalin (2007), Guermandi and Rossenbach (2013), Novaković et al. (2016).

the archaeological discipline in the past, today, when more than 90% of projects are of a preventive nature, and the majority of them are funded from non-academic resources, it is very important to understand the differences and consider them when discussing the future of the archaeological discipline. Already for some time it has been very clear that by far the greatest amount of new discoveries and forms of evidence in archaeology derives from preventive research, thus rendering archaeology a 'data-driven' discipline. One could hardly find another discipline where the quantity of new data has increased by several orders of magnitude, almost without any control of what research, and where, takes place.

This situation requires serious reconsideration for the future of the archaeological discipline. On the other hand, this is not the case with disciplines traditionally considered close to archaeology, e.g. art history, history, anthropology or ethnology, where one could hardly speak of any new pieces of evidence discovered 'by chance'. In another paper (Novaković, Horňák 2016, 32), we have posed a rhetorical question – what would happen with our knowledge of ancient history, and ancient history as a discipline, if over the last two decades some 10,000 new fragments of written sources were discovered 'by chance' in the Mediterranean? The comparison is, of course, rather exaggerated, but it nevertheless illustrates the situation in archaeology today, where it is the 'chance' discoveries that sustain the discipline. In this sense, a great deal of archaeological practice is moving away from the traditional goals and disciplinary practices of the humanities and getting closer to the engineering sciences, providing a series of science-based practical services.

The discussion about whether preventive research achieves the levels, standards, and state of the art of academic research is, to some extent, misleading. It actually refers more to current practices and routines than to conceptual frameworks of both academic and preventive archaeology. The truth is that, in many situations, planning large fieldwork campaigns in preventive circumstances may not be optimal due to the lack of time, infrastructure, other resources, and funds; also, the implementation of fieldwork may be substantially conditioned by time pressure, inadequate temporary living conditions and highly stressful working conditions compared to the academic research context. But although the conditions in preventive contexts may not be optimal, this is not the key difference between the two. The essential difference is in the conceptualisation of research: whereas academic archaeology performs its fieldwork with a particular problem-oriented research design in mind, no such design is possible in preventive research, and even less in rescue and salvage situations.

But this does not necessarily diminish the potential and quality of preventive research. Instead, detailed individual problem-oriented designs should be replaced with standards against which the quality of preventive archaeology must be measured. These standards cannot include specific research questions or agendas, but, on the other hand, they can provide a suitable framework for addressing at least some of the major research issues in archaeology (e.g. adequate description of the evidence, chronology, classification of finds, stratigraphic history of sites, phasing, cross-referencing stratigraphy and finds, and a kind of 'general' interpretation of sites and finds). It is fair to say that sometimes the sampling and collection strategies, accuracy of measurements, and objects of observation would not satisfy the requirements of individual, problem-oriented research designs; but, on the other hand, the evidence acquired in preventive work would often be

completely missed in academic research, and would never pose new research questions. Indeed, what we see here is actually more the question of how to combine the research standards of preventive archaeology and various academic agendas.

The question of standards in preventive archaeology is beyond the scope of the CONPRA project and its publications, and should be addressed by national bodies responsible for heritage protection and also involve academic institutions. While most countries in Europe implement various kinds of preventive archaeology, only a few have adopted true standards which guarantee quality (e.g. the UK, the Netherlands, Slovenia). Indeed, it is difficult to overestimate the importance of standards in preventive archaeology and, for that matter, in archaeology in general. With the development of preventive archaeology, numerous new professional subjects (public and private) performing research and associated services have emerged and are competing in the market of archaeological research services. In such circumstances, it is the standards (and their fulfilment) which are the most efficient tool in securing adequate quality control.

In countries lacking standards of archaeological research, their place is, more or less implicitly, occupied by the long-standing procedures and routines practiced by top academic institutions. There are many reasons why this is not a good substitute for standards; academic institutions simply have different archaeological agenda and priorities, less experience in day-to-day fieldwork in stressful conditions, and normally do not train personnel for preventive research. Moreover, there is no assurance that, for example, one detailed academic problem-oriented excavation would adequately treat evidence not directly related to the research problem. This is not because one would consider such evidence less important, time-consuming or, even worse, too expensive regarding the allocated research budget, but simply because of a lack of standards (i.e. the necessary level of recording and treatment of data and objects). It all comes down to professional ethics. And it is here where the subjects in academic and preventive archaeology are not in equal positions. Archaeological stakeholders in preventive research need to go through a series of frequently painstaking negotiations, compromises, and improvisations in order to secure adequate working conditions, funding and appreciation of their work. The developers are not looking for the most excellent archaeology, but instead for the cheapest.

By saying this, we are not trying to widen the gap between academic and preventive archaeology, but rather to attempt to bridge it. Indeed, there are many aspects in which academics can take part in preventive archaeology. By this, we do not envisage academic institutions simply competing in the market of archaeological services in preventive contexts, which seems to be the case in countries where academic institutions have to survive serious budget cuts and personnel shortages. Instead, good knowledge and experience in organising and implementing preventive projects on different scales, strategies of heritage protection, and some sound reasoning may lead to highly effective involvement of academics in preventive practice. They may act as consultants, reviewers, or specialists for a number of different analyses; and, why not, academic institutes can be members of consortia created ad hoc for meeting the most challenging demands in preventive archaeology. There are some exemplary cases of these practices. The final result is not only more and better developed archaeology, but also the creation of more productive frameworks for facing the challenges of a highly data-driven discipline.

And there are also some great advantages of preventive over academic archaeology. First and foremost is the great coverage of different areas which, under normal conditions and circumstances, would not be investigated to such a scale and extent by academic research alone. Let us just think of the thousands of sites and new lines of evidence discovered in urban zones. No academic research programme would have a chance to excavate even a small percentage of urban areas that are under constant pressure from land development projects. Though these urban 'windows of opportunity' are normally open for a very short period of time, it is they that have yielded extraordinary evidence for the history of our towns.

Although one could say that preventive research has little influence on the choice of locations to be examined, and hence their contribution to major scientific questions is less harmonised with academic agendas, it is in the long run that preventive archaeology demonstrates its high relevance for academic research. It does not provide quick answers to individual research problems, but by undertaking thousands of trial trenches, surveys and excavations over a decade or two, whole regions or countries are 'sampled' in an extraordinarily detailed way, with no ecological, morphological, settlement or historical area left out. A lot of the results of such continuous 'sampling' are yet to be properly evaluated, but what is already clear is that these results, though in many cases still interim and partial, generate new important research questions and influence academic research agendas. The most illustrative cases are numerous projects along motorways or similar linear features crossing large areas of space, which have brought to light so much new evidence that successfully challenged and contrasted with long-existing interpretations of demography, settlement and chronology, and that shed a completely new light on our past.

Another important outcome of the developments in preventive archaeology is the considerable increase in the number of trained professional archaeologists capable of day-to-day coping with the unprecedented amount of preventive research. The truth is that such an increase in the amount of work conducted was only possible with the increase in the number of archaeologists, but it is also true that a wider professional community could put more pressure on improving the quality of heritage protection and its practices. This is the aspect that the CONPRA project is especially focused on. The development of digital technologies for data retrieving, recording and processing, coupled with the recent developments in remote sensing techniques, non-invasive archaeological methods, and integrative powers of geographic information systems, web servers, and IT technology in general, pose a great challenge to archaeology professionals. To put it simply, if a developer hires a team of experts able to produce a final detailed building plan of a new settlement using e.g. LIDAR, aerial mapping, underground surveying, modern CAD tools, field laser scanning, 3D modelling, etc., within a period five times shorter than some ten years ago, similar is expected from preventive archaeology. The challenge can be confronted only by using the same tools as professionals in other fields and developers.

This, of course, raises the question of the education of archaeologists. It is illusory to think that students will quickly get familiar with a myriad of new technologies that emerged during their studies. Simply, there is not enough time, resources and trained teachers to promptly react to all the novelties appearing daily. New techniques and technologies also need to be properly contextualised and experimented with prior to becoming

routine in archaeological practice. And, in many cases, they also have to be properly acknowledged by the professional communities and bodies responsible for protection of the archaeological heritage. With the great increase in the number of preventive projects, it becomes even more evident that training in new techniques and procedures is a career-long endeavour, and could be implemented in a number of different ways, not all akin to academic training. Here we refer to different forms of apprenticeship, secondments, various ad hoc courses, and different forms of learning-through-work. It is important to note that a great deal of today's archaeological 'experts' in CADs, GIS, 3D scanning, 3D photogrammetry, LIDAR, geophysics, various laboratory analyses, etc., are originally archaeologists by academic training, but self-taught in the course of their careers and practice.

The initiative for the CONPRA project came, indeed, from such a self-taught population of younger professionals from private and public (academic) institutions working in preventive archaeology. The CONPRA project was primarily aimed at assisting in building capacities for facing current challenges in the practice of preventive archaeology. The project partnership is composed of two small private enterprises: Via Magna s.r.l. (Martin, Slovakia) and Terra Verita s.r.l. (Prague, Czech Republic), and two university departments of archaeology (University of Ljubljana, Slovenia and University of Belgrade, Serbia). Except Serbia, in all the other countries the market of archaeological services has developed more or less in parallel (and in association) with preventive archaeology. The development of the market of archaeological services created new situations in archaeological preventive practice which, until the 1990s, used to be completely in the domain of public institutions and negotiations between (mostly) public stakeholders of spatial development.

In observing such markets in Slovakia, Slovenia and the Czech Republic, a very important fact was identified, that of the rather locally based work of private enterprises. These enterprises mostly work close to their home base, have very few (if any) contacts with enterprises outside their country (or even their region), and cannot easily follow the developments and achievements in academic archaeology on a trans-national level; their major contacts with academia are through students they occasionally hire and occasional contacts with professors or established researchers in the case of very interesting discoveries. They are also lacking in professional associations (such as for example CIFA – the Chartered Institute of Archaeologists in the UK) which could lobby for their professional interests, develop and promote common standards and codes of conduct, analyse trends and fads in the market, and so on.

Such conditions are definitely not favourable for investing in new knowledge, skills, and equipment, if clear economic gains are not anticipated in the near future. The fact is that, in all European countries, markets of archaeological services are quite volatile. Mostly dependent on the intensity of development and spatial planning, it is archaeological markets which are the first to experience crises in the development and construction sectors. Being a 'miner's canary' (Schlanger 2010, 108) is not a favourable role for any economic enterprise. On the other hand, academic institutions in the CONPRA countries (and elsewhere as well) also suffered substantial setbacks due to the global economic crisis since 2008, which excluded them from a great deal of investments in developing and applying new technologies in archaeological research.

A large number of enterprises in preventive archaeology in the CONPRA countries fall into the category of small or micro-enterprises. Very few of them have more than 10 permanently employed professionals in archaeology and associated fields pursuing archaeological research. Most of their work is done in the field (e.g. archaeological excavation, archaeological surveys, archaeological monitoring) and also includes processing of the field data and the material evidence. In circumstances where most of the enterprises could employ only a very small number of experts, narrow specialisation for certain aspects of archaeological work is rarely the case. Quite the opposite, it seems that it is the 'general' field archaeologists for whom the demand is the greatest, those able to competently and efficiently master a large span of archaeological skills in the field and in data processing.

CONPRA publications are targeted primarily at this profile of experts and enterprises who have certain experience in conventional archaeological fieldwork, and who can considerably enrich their skills by using several new techniques and tools in their everyday work. Indeed, while it is of crucial importance that field archaeologists understand these methods and techniques, it is even more important to understand where and how their routine work can be upgraded and made more efficient or accurate, and hence more competitive.

The CONPRA project was focused mostly on the development (and transfer) of knowledge in those aspects of archaeological fieldwork which are currently among the most promising and 'prolific' in archaeological practice, and which have shown clear advantages in terms of efficiency, accuracy, and time and labour requirements. They are all strongly based on new digital technologies of data retrieval and processing, and have proved successful in various types of archaeological research, both academic and preventive. It is not by chance that most of them are well-suited for non-invasive archaeological research (various surveys, remote sensing and other types of reconnaissance) since it is these methods and techniques that are crucial for making the ultimate decision for an entire excavation. Preventive archaeology is, in the first place, about testing and sampling, and providing sound evidence for prescribing costlier actions, e.g. excavation. In a certain sense, it is successful testing and sampling that are the ultimate proof of the relevance and necessity of preventive archaeology.

The CONPRA Series comprises four volumes, which are all a result of the joint work of secondees, tutors and other experts involved in the project:

- *3D Digital Recording of Archaeological, Architectural and Artistic Heritage* (Vol. 1)
- *Using Aerial Photography and LIDAR in Archaeology* (Vol. 2)
- *Introduction to Managing Datasets in Archaeology* (Vol. 3)
- *Virtual Reconstructions and Computer Visualisations in Archaeological Practice* (Vol. 4)

It is these fields, we believe, where major improvements have been made in recent years, and which will gain in importance in the future. All four fields are strongly based on modern IT and digital technologies, and it is essential that practitioners in preventive archaeology implement them in their everyday practice. These technologies will increase the capacities of many private or semi-private SMEs and other practitioners in preventive research, not only in the sense that they could complete their tasks faster

and more accurately, but also that they will be able to significantly contribute to the positive image of (preventive) archaeology as a whole, thereby increasing its relevance in modern society.

At the end of the day, it is always the question of relevance and added (social and other) values against which preventive archaeology and heritage protection are measured. Our societies do recognise heritage as a value worth protecting and enjoying. To this end, a series of legislative documents were produced and a number of public institutions established with the aim of protecting the heritage. Yet, heritage, archaeological in particular, is always challenged by spatial development. Whilst weighing the values of development and heritage, both are primarily considered as a resource, and it is in this context, especially at local levels, that heritage protection is frequently considered an obstacle to development or even an unnecessary cost. Heritage is a resource where investments bring 'profit' in the very long run, whilst a great deal of development (especially privately funded) is expected to pay off in a much shorter period of time. But let us look for a moment at the historical centres of many European towns. They all attract large masses of tourists and generate substantial income, yet this was possible only through decades of implementation of a careful protection policy and long-term efforts.

The 'frustrations' that developers are facing can be even more severe if preventive archaeological research is not done according to the highest professional standards or, even worse, if very costly excavations turn out almost 'fruitless'. As has been already said, developers would go for the cheapest archaeology, and not the highest-quality one. Unfortunately, recent evidence from many countries (e.g. Aitchison 2009; 2014, and accompanying national reports; also in Guermandi and Rossenbach 2013) shows that enterprises are willing to charge prices that barely cover their costs, just to be able to survive another season. Such a situation is increasingly worrying, since it undermines the quality of preventive archaeology in general and, to remedy this situation, the most urgent task of the relevant public bodies and legislators is to secure adequate minimum conditions for preventive research.

In the meantime, it is up to the enterprises and all other subjects acting in the field of preventive archaeology to invest in knowledge and skills, in order to make them more competitive and diversified. The CONPRA publications aim to contribute to this process.

INTRODUCTION TO VIRTUAL RECONSTRUCTIONS

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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 inter-disciplinary, 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 para-dox 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, draw-ings, 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, accu-rate 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 struc-tures 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 bet-ter 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 fu-ture generations of archaeologists and IT users.

Every day many gigabytes of data are being produced in order to replace excavated struc-tures 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).
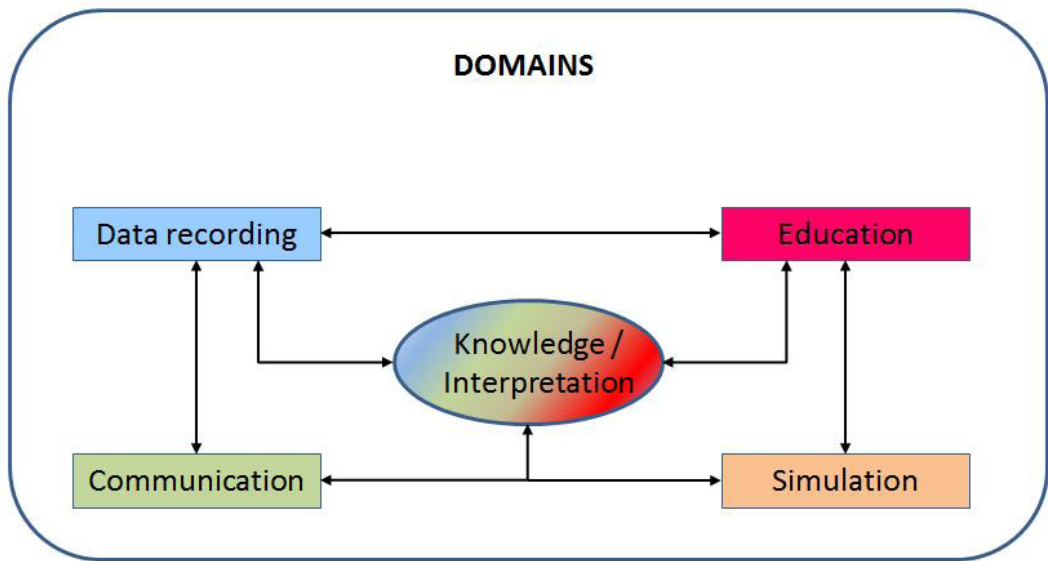
Figure 2. Domains of digital knowledge.

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.

ABOUT DIGITAL FIELD DOCUMENTATION

Nenad N. Tasić (University of Belgrade)

An important application of 3D computer graphics in the world of archaeology is in documenting the excavated features. Since archaeological excavations constitute removal of deposits from the site, the need to document in a comprehensive and detailed way each feature removed during the excavation requires methods of graphic and photographic documentation that can support traditional 3D modelling. This technique can be used both for recording of individual finds and also for features included in a GIS system in which the 3D data are functionally integrated. From this point of view, the combination of GIS systems in archaeology and the development of 3D laser scanning and image-based 3D modelling techniques resulted in the emergence of experimental systems of 3D GIS. This system is able to visualize 3D data within the geographic information system, such as point clouds from laser scanners.

At the landscape scale, digital 3D modelling and data analysis allow archaeologists to integrate different archaeological features into a physical context in order to better document the investigated area. At the monument/site scale, 3D techniques can provide accurate measurements and objective documentation, as well as a new aspect or a different point of view at the recorded features. At the artefact scale, 3D modelling allows the reproduction of accurate digital/physical replicas of every artefact.

3D modelling can also be extremely useful for the identification, monitoring, conservation, restoration, and promotion of archaeological findings. Archaeological heritage is under constant threat and danger. Architectural structures and cultural and natural heritage sites are exposed to pollution, tourists, and wars as well as environmental disasters such as earthquakes, floods, and climatic changes. Hidden aspects of our cultural heritage are also affected by agriculture, changes in agricultural regimes due

to economic progress, mining, gravel extraction, construction of infrastructure, and expansion of industrial areas. In this context, 3D computer graphics can support archaeology and the politics of preservation of cultural heritage by offering scholars a "sixth sense" for understanding traces of the past, whilst at the same time allow us to experience it.

Each product of human intentional or unintentional actions, such as artefacts, structures and cultural landscapes, has a 3D constitution and so it is possible to describe it using three spatial dimensions. The shape of artefacts, expressible in 3D, suit the artefacts' purposes from the perspective of function, social or symbolic meaning. These objects have long dwelled in their 3D space, not always the one in which they were deposited by their owners, but a different one, dictated by various taphonomical processes. Nevertheless, the position of artefacts and their spatial context offer archaeologists many clues for deciphering their usage and meaning. The context and the taphonomy are extremely important because they often allow archaeologists to interpret the purpose of otherwise static and enigmatic archaeological finds.

Understanding space and its importance for contextualization of structures and artefacts was always inherent in archaeological method. The dimension of space is closely related to the basic archaeological methods: analysis of typology of the materials and the sites' stratigraphy.

Digital 3D documentation allows iterative research of archaeological context after the excavation. Unlike traditional 2D technology, 3D recording of deposits allows archaeologists to develop more detailed understanding and different analyses of the complex deposits and artefacts they excavate.

ArchaeoPackPro! a software for digital field documentation

3D recording methods have always been dependent on the contemporary technological possibilities. In accordance with the practices of other disciplines, three-dimensional space has routinely been reduced to only two dimensions, which can be expressed on paper. Archaeological sites have been transformed into sets of plans and trench section views, finds have been transformed into drawings and photographs. This tendency to simplify archaeological reality persists even today, even though the tools have been developed that provide a more realistic and visually more effective documentation (Tasić & Jevremović 2003).

Within the CONPRA project, a software (ArcheoPackPro!) designed and used at the Department of Archaeology in Belgrade and in archaeological excavations at the site of Vinča near Belgrade was implemented. This is a software conceived to equip archaeological teams with a comprehensive data management for archaeological fieldwork. With numerous possibilities that modern computer systems nowadays offer, ArchaeoPackPro! was designed with the aim to replace the old-fashioned procedure of data input and thus help speed up the fieldwork, as well as to improve the quality of collated documentation and introduce new methods of data processing and analysis.
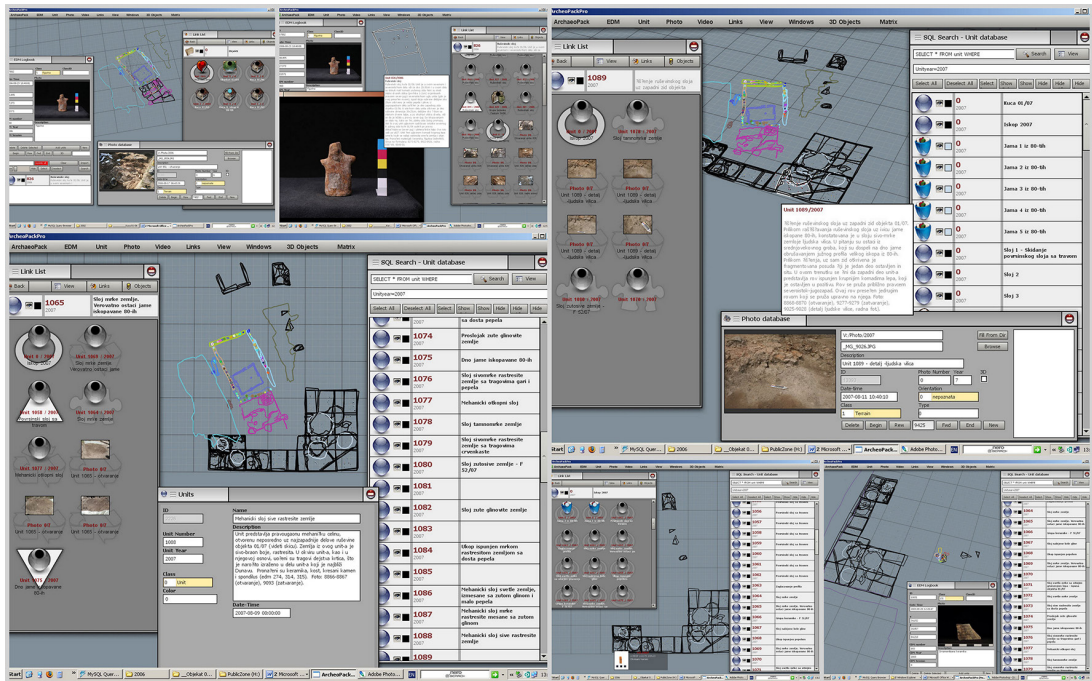
Figure 4. Screens from ArchaeoPackPro! software for 3D field documentation management.

The software package is based on a modular system and access. Every element of the system communicates and exchanges the data with other elements, but is at the same time independent. An approach like this enables constant upgrading and introduction of new options and possibilities into an ArcheoPackPro!.

ArcheoPackPro! was designed to be used in three separate processes of archaeological research:

- Fieldwork data recording and storage.
- The analysis and interpretation of archaeological materials.
- Archiving old field documentation.

Since detailed, accurate and precise field documentation represents a key premise for archaeological interpretation and for a professional approach in explaining archaeological finds, it is easy to understand that the threes aspects are of essential importance for archaeological fieldwork.

PHYSICAL VS. VIRTUAL RECONSTRUCTION

Stevan Đuričić (University of Belgrade)

Conservation and restoration entail treatments of structures or objects of material culture from the past in order to preserve and present them. The principles upon which experts in these fields conduct their work have to fulfil ethical, aesthetical and technical regulations which are very strict; thus, the rules which they must obey are, in most cases, rigid (e.g. The Venetian Declaration, The Burra Charter). The ideas leading to different versions of the final product, developed during the process of conventional reconstruction, often remain unrealized. The option that is usually picked as the final choice is the one which is considered to have the smallest window of error probability. Contrary to the physical, three-dimensional digital reconstructions allow for more freedom in the interpretation of the gathered data and do not bear risk of making an irreversible mistake. Virtual reconstructions are possible even in cases where physical reconstruction is not an option (either the objects and structures are poorly preserved, or there are not enough resources or time for physical reconstruction). Due to the fact that archaeological excavations are often destructive, and a lot of important data are preserved only in archaeological documentation, detailed graphic, photo- and video recording is necessary in order to preserve information about investigated structures and contexts. Three-dimensional scanning and photogrammetric recording can be considered as the optimal methods of visual documentation. Using these methods, all shapes are measured and recorded, and photographs are used as textures, so that detailed geo-referenced record is easily obtained. The end product is a three-dimensional model which can be upgraded in some 3D modelling and animation program.

Conservation guidelines for virtual reconstruction

One of the most important conservation guidelines is that the reconstruction has to preserve the authenticity of the original. At the beginning of the 20th century, Benedetto Croce developed a theoretical framework for this field (Croce 1990) and his work has become a cornerstone of Italian conservation philosophy. Also, his influence in defining basic principles of conservation should be pointed out. Further, Giulio Carlo Argan and Cesare Brandi, two notable conservation theorists, proposed the basic principles of theory of conservation (Jokhileto1994).

Main aspects of the authenticity principle are:

• Authenticity in design;
• Authenticity in manufacture;
• Authenticity in harmonization with the surroundings;

For some elements of the reconstruction, especially when buildings are concerned, analogies with other contemporaneous structures of the same type and function are used. That said, one should have in mind the selection of only unambiguous and secure examples. This is especially important when working with buildings from the historical periods which are constructed from hard materials. In some cases, although rare, original construction plans have been preserved. This is then not a reconstruction, but a restoration. When there is not enough of information for a reliable reconstruction, the problem should be approached with extreme caution. Due to the fact that the degree of reversibility is low when restoring structures made of hard materials, any correction of errors made during the reconstruction process is hardly feasible. The rule that must be followed is to clearly separate the original parts from the ones added during the reconstruction, which applies to both movable (i.e. objects) and immovable (i.e. structures) features (The Venetian Declaration, Article 12).

Respecting reversibility is the next important criterion that should be met when selecting the method and the degree of restoration. The risk of error which occurs when restoring objects or structures made of delicate and friable materials is far greater than the one present when dealing with object/structures made of hard and durable materials. In the first case, the process of structural stabilization can be performed. We can consolidate unstable materials, but even then, there is the risk of picking a wrong consolidating agent. Consolidation is one of the high-risk procedures, especially when applied to large structures, due to the fact that the degree of reversibility is extremely low, and it is virtually impossible to repeat the process. In some situations, it is best not to attempt physical reconstruction at all and instead do graphic reconstruction, which is one of the ways to present ideas for the subsequent virtual reconstruction. Virtual reconstruction is a very good solution, as it provides visualization of the reconstruction ideas without any physical interference with the actual archaeological feature.

Virtual reconstructions based on detailed documentation allow us to test different ideas and assumptions, without violating the basic principles of conservation and restoration. When archaeological sites are investigated systematically, data from more recent investigations tend to change previously developed ideas and reconstructions of the excavated

structures. When structures are physically reconstructed, it is often hard or even impossible to make any necessary modifications suggested by newly conducted analysis and fresh results, which is not the case when the reconstruction is carried out in virtual reality.

Even though 3D reconstructions offer a lot of possibilities and many advantages in comparison to physical restoration, this does not mean that the two methods exclude each other. On the contrary, physical reconstruction will probably never be replaced, because of the value of the actual archaeological finds. The excitement these provoke when they are presented can only partly be substituted by exhibiting replicas or virtual reconstructions. Also, beside restoration of the original appearance of archaeological objects, the basic purpose of standard conservation and restoration is the preservation and consolidation of structures and objects, and their protection from further decay, and this requires treatments of the original finds.

Three-dimensional models can be considered as one of the methods of preventive protection, first of all because they aim to produce a genuine image of the original which can the replace the original in some aspects of research and in some analysis, mostly the ones using visual methods or determining the volume of a structure and so on. In this way, the need for physical contact with the original structure or object is avoided. This is highly relevant to movable objects, because every time they are removed from the controlled environment they are under the risks of disintegration.

The production of replicas is a traditional method of archaeological conservation, which, in the preventive protection sense, has the same function as a 3D model, but can additionally serve as souvenirs, and this makes them profitable and suitable for promotion of cultural heritage. The problem occurs when a print has to be taken in order to make a mould, in which case the original object comes into direct contact with physical, chemical and biological (if the materials are organic) agency of the materials, that at certain point can have negative effects. The development of three-dimensional printing now enables printing of the replica of an object, based on the 3D model, and the original object stays safe in a museum.

In the case of physical reconstruction, the restoration relies on the remains of the original structure or object, following all the principles of conservation and restoration. One of the first tasks in virtual reconstruction is to create a 3D reconstruction of the excavation area and the archaeological remains. Regardless of whether a 3D scanner, LIDAR, drone, or photogrammetry is used, the end result is a "wire frame" and the texture that can be imported into software suitable for three-dimensional modelling and animation.

After making a 3D model of the preserved parts, all available data on the original structure or object are collected and technically prepared for a 3D upgrade. It is of vital importance to obtain all visual (graphic and photo) recordings, and it is often necessary to consult excavation dairies, geodetic data and specialists' reports. If the structure/object being reconstructed has been published, it is recommended to gather all the relevant literature. If the data are insufficient, but the structure/object is available for observation, it is advisable to gather additional data, first of all through observation, photography and geodetic measuring.

The next step is the analysis of the data and the development of the reconstruction plan. If the reconstruction of large complexes is planned, the expert team consisting of

an archaeologist-excavator or an archaeologist-museum curator, a 3D modelling specialist and a conservator should be formed. When reconstructing urban units, an architect must be included on the team as well. They make the core of the team and they should closely cooperate during the process of reconstruction; if needed, the team can also include other specialists.
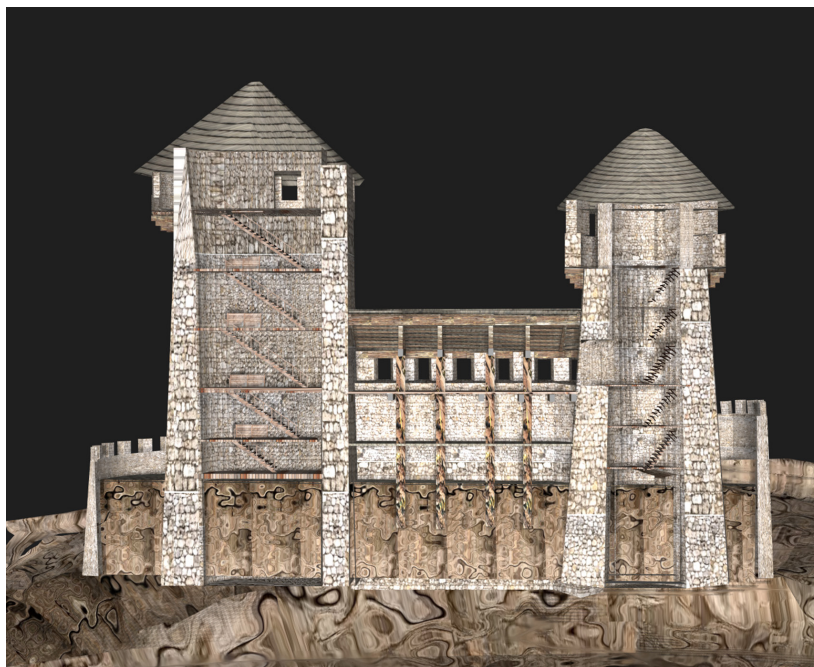

Figure 5. A Cross section of a medieval fortress.

Figure 6. Reconstruction of a kiln from Neolithic village of Stubline, Serbia.

BRIEF OVERVIEW OF EXAMPLES OF VR PROJECTS

Zuzana Rejdovianova, Andrej Žitňan, Milan Horňák (Via Magna), Jiri Hrubý &
Daniel Hlásek (TerraVerita)

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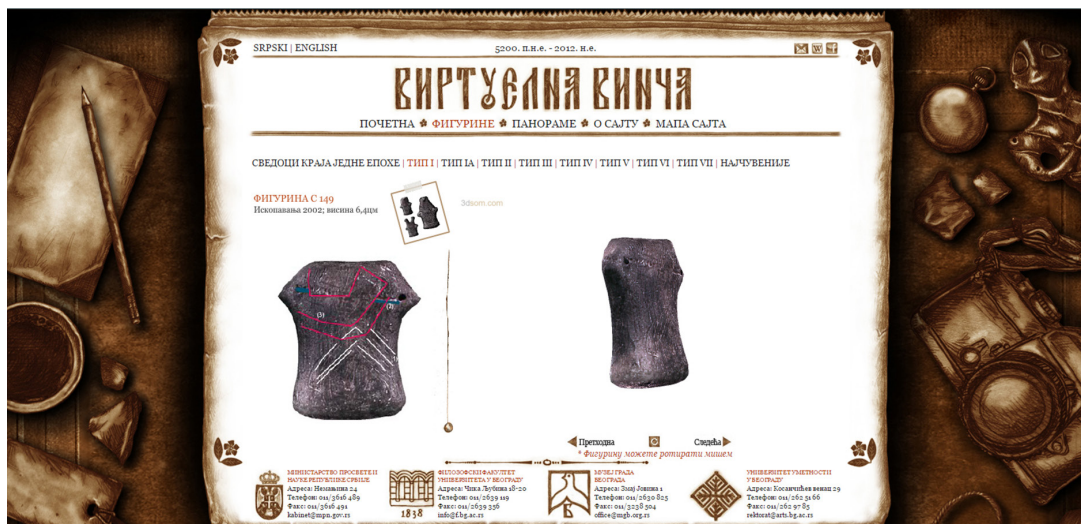
Figure 7. Page with applied 3D models of the Vinča culture figurines.

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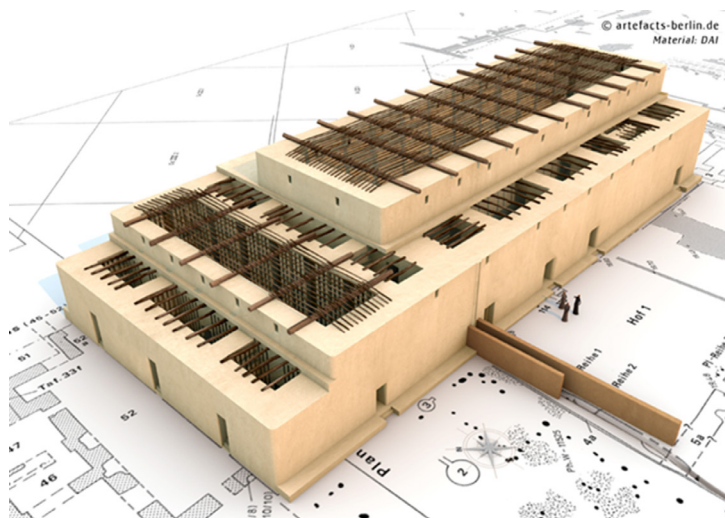
Figure 9. 3D interpretation of a building from Uruk (copyright DAI, Berlin).

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://3di-cons-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.

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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).

VIRTUAL RECONSTRUCTION OF THE VINČA-BELO BRDO SITE

Jugoslav Pendić (University of Belgrade)

The complex task of bridging the gap between photogrammetry or TLS/ALS-captured data and its visualization has many aspects, each of them heavily affecting the final output. This becomes even more apparent when dealing with information acquired on large scale surveys – which in practice can be described as individual projects covering areas of more than few tens of hectares; whilst data can always be displayed in a static form – a 2D rendering in a specialized GIS/supplementary software, or an output formed in quasi-3D format (2.5D), this does not quite satisfy the needs of the reconstruction and visualization of environments/landscapes of the past.

In this kind of situations, a decision can be made to turn to 3D modelling software that is able to cope with our input data, whatever the origin of the data. For the reconstruction of the Neolithic site of Vinča, Serbia, our sources included a combination of photogrammetry record and the open-access spatial data, such as SRTM (1 arcsecond) terrain models, freely available from the USGS repository. The core photogrammetric model consists of little less than 1000 photos of the area of 1 km^2. The additional area provided by SRTM extended a few kilometres down the Danube and was used as a means of closing the scene; the nearby Ritopek hill and the Vinča hill together form an open valley that marks the boundaries of the reconstruction.

It is important to note that the laser/photogrammetry scanned surfaces and reconstructed areas for the use in virtualization are not the only possible sources. A number of data sources can be and have been used for past landscape visualization – e.g. the tools like geophysical prospection with ERT (electric resistivity tomography), auger drilling, reflection seismology (Fitch et al. 2007), GPR (Watters 2009)– as long as they allow to single out properties of a horizon that is of interest to the researcher. Depending on the demands of a project, these

can be joined in formats and ingested by modelling software. Whilst we had ERT and GPR results available for a relatively small portion of the terrain, our choice to exclusively rely on geomagnetic survey conducted in Vinča, SRTM and photogrammetry record was guided by the desire to represent the wide area of the settlement in an immersive way – to tackle the visualization of the community, rather than small sections provided by other geophysical methods. However, they came in very handy when evaluating the sources we used. How?

Aerial imagery was acquired for the highly-urbanized area that contests the archaeological site on a daily basis: this takes a toll on our intended use of the dataset as a stage in the process of reconstruction. In essence, we needed to get data on the bare ground (or as close as possible to it) which were to be used for generating a continuous surface. Most of the professional software that deals with surface reconstruction from images has an option for exporting data, point clouds, in a format that can be read by standard GIS software (such as GlobalMapper, ArcView, Qgis). For example, *.las* output can be readily filtered in a number of GIS solutions. In this way, it is possible to calculate and extract only the lowermost points in a processed area – points that, based on the parameters that the researcher would find acceptable, could represent bare ground surface. It is worth mentioning that this is, by far, much more straightforward in ALS datasets, when utilizing benefits of the last echo in a signal. For a terrain documented with photogrammetry, an option is available in Agisoft Photoscan to internally calculate the similar output, although it follows the same rules – if a point to be reconstructed is not seen on 3+ photos, it is not possible to get an optimal (if any) result. Thus, when working with a terrain covered in dense vegetation, such as is the case in late spring/summer, it is better to postpone the survey until winter or early spring. This is certainly an aspect that needs to be kept in mind when designing the project.

In the case of Vinča, it was possible to reconstruct the base surface in a portion large enough to commence with the next stage: adaptation of the mesh and the combination with SRTM dataset. The adaptation was necessary due to the fact that the data obtained from photogrammetry software come out as a massive polygon count. Depending on the size of the project, the poly number can reach several millions, and a number of them often represent very even (flat) surfaces that could equally well be represented with a smaller number of triangles/quadrangles. In addition to redundancy, one must think of the poly count budget for the reconstruction project and plan ahead: some parts of the terrain will require more data to work with to be finely modelled and, eventually, the project will reach its poly count budget when hardware limitations will become apparent and will affect the workflow. Whilst there are a number of techniques accessible by different levels of experience that address this, it is generally a good practice to think about optimization whenever possible.

For the Vinča site surface it was necessary to reduce the poly count (of 5,000,000) and remove the traces of modern house positions and any other irregularities that disrupt the flow of the polygons. For this we turned to the MeshLab (Cignoni et al. 2008) designed by Visual Computing Lab – ISTI – CNR. This is a freely available solution that deals with point clouds and meshes (surfaces) for numerous uses – TLS scan registration, meshing, referencing, editing, texturizing, to number a few. Using re-meshing options and various filtering algorithms and decimation algorithms, we were able to join in pre-registered meshes of Vinča aerial survey and SRTM model into a seamless whole, which had an even polygon flow and density adjusted to the specific needs, with a higher number of polys where we needed to tweak the geometry of terrain to a greater degree – notably the position of the Neolithic site.

What needs to be emphasised is that, this is not the only way of solving the transfer of spatial data into a 3D modelling and interaction environment. The terrain itself can be generated using a greyscale image in pair with distortion modifier on ordinary plane surface; the image, in this case, would be a DTM that has elevations codified on a 255 B/W scale, from lowest to highest, where software uses the provided information to generate nuances in the terrain, in a pixel-for-poly manner. A similar technique was reported to be highly suitable when using a LiDAR DTM in Crytek game engine (Challis & Kincey 2013) to represent archaeological content in the form of SEG (Serious Educational Game (Annetta et al. 2013)) where a full-blown phenomenological study of landscape could be mounted, in pair with the interaction of the researcher with archaeological remains present at the site – all within the virtual environment.

Our next task was to delineate position of the site proper – the central area for which we know most the activities that occurred there. For this we used results of the geomagnetic survey to form a boundary area towards inland where the number of structures was expected to decline in the reconstruction. This was also done using Meshlab, by applying the image alignment filter (Corsini et al. 2009) and the texture projection via parametrisation and projection (Calieri et al. 2002), where the image aligned and projected was a true-ortho imagery of the site containing digitized positions of features identified by geophysics. The issue of correlation between the virtual environment and the information collected through fieldwork is an interesting one; whilst our approach is a very simplified one, an alternative marriage between GIS data and VR via customized tool was proposed previously (Callory et al. 2005) that would give rise to a completely novel approach in methodology of everyday field duties.

Once the positions of features are projected, and the portion of the site removed by geological processes and excavations during the 20th century acknowledged, further modelling required that the missing parts of the terrain be artificially added. This is a point when a choice of 3D modelling and rendering software needed to be made. The current market offers a number of solutions that can be of use; however, from a perspective of an archaeologist, one should first carefully determine the aims of the project or the company practice. The relevant commercial software usually does not represent a great pressure on the budget, but it may be better suited for professional visual artists with specific requirements. Our choice was to use Blender, a freely available solution that already has a large number of users well-familiarized with photogrammetry procedures. Within Blender, several engines for rendering are available, with Blender Cycles as the most intensively developed one. Cycles goes out of its way to present realistic lighting conditions of every scene fed into it; in combination with a comprehensive nodal system of shader, texture and bump effect application to an object/frame, we considered it to be the best available solution for our reconstruction.

Internal sculpting tools were used to edit the terrain, delineate water flow of the Bolečica river, cut paths and create an even surface on slopes where the houses and other structures were to be placed. The missing parts of the site were modelled from the flat surfaces and were given the form of a terrain along the course of the Danube in prehistory, at the time of the final occupation phases of the site. Across the river, which was represented by a plane with a nodal system combining bumps and wave texture with the appropriate colour and reflection, a segment of terrain was added and modelled without constraints.

In general, the only constraints were imposed by the scale and geometry of the terrain that was reconstructed with UAV documentation, and this one, too, was processed in a way to visually remove sedimentation from the periods following the final Neolithic phase.

Once we were satisfied with the result in this stage, we started the application of textures on the landscape. The approach used relied on an unwrapped UV surface that could not be additionally changed (every subsequent change would affect the UV and produce holes in the texture flow, which would be remedied by repeated UV unwrapping, but that would, in turn, cause distortion in image mapping). In the previous step, we modelled the terrain; now, following the curves and intended use of the surfaces (i.e. paths, areas immediately close to the houses, slopes, areas under vegetation), the images were applied. One cannot stress enough the importance of the choice of images that will serve to achieve a realistic depiction of the surface. Whereas it may seem easy to just download any kind of texture from one of the numerous web-based sources, some thought should be given to the local geology and pedology. It hardly makes sense to use craggy limestone to represent fine alluvial sedimentation; also, not all images that correspond to the geological background will give a satisfactory output. There is nothing preventing one from visiting the site and acquiring images of the ground, grassy areas and other details, and building a custom set of textures.

Attention must also be paid to texturizing large landscapes, since several problems arise when working on this task. First and foremost, tiling of the textures; whilst a practitioner will almost certainly use seamless textures (i.e. images that were processed in image editing software in such a way that they are seamlessly repetitive along principal axis), this still does not remove repetition of the pattern of the image. In other words, depending on the scale of the applied texture, tiles will become visible on the surface, especially when looking at it from above or from a distance. Increasing the scale value will solve the problem with "distant" surfaces, but the textures close to the camera will suffer blurring and will be non-engaging for the viewer. Our solution to this problem was to use a composite texture, built of images used to represent different land classes (grass, second grass type, dirt, mud) that could be stored in a single 2048x2048 pixel sized image as RGBA channels, and later separated and multiplied by representative colour (brown for ground, green for grass, etc.). This image was mapped using splatter texture (another example of mapping using greyscale imagery). With the internal tools in Blender, another 2048x2048 image was produced that was coded in nuances from white to black; a specific value on the scale corresponded to the assigned range of particular texture stored in a channel. In this way, we controlled the distribution of imagery across the terrain. The advantage of this is that textures overlie one another without losing the depicting character of a particular land class, but reducing the tiling immensely. Also, in addition to this, the increased scale value textures could be draped on to this (and multiplied) thus further reducing the repetition.

The next step was the choice of lighting. For this, too, multiple options exist – some of the useful methods are building a skybox/skydome and lighting it with a combination of sun lamps or, and this was our choice, to illuminate the scenery with a HDR panoramic sky image, which simulates effectively behaviour of the daylight – a single small source of light in combination with the dissipation and reflection of light from the sky/terrain.

Having defined the land classes, site position and boundary in virtual space, it was possible to start "populating" it with content. In order to achieve a realistic look, and engage the viewer, we relied on the palaeovegetation distribution proposed by the archaeobotanist.

However, numerous classes of plants that could be expected in the area of the Late Neolithic settlement in Vinča would be indistinguishable to an untrained eye, and would affect the visualization to a very small degree, but the attempt at generating a separate model for each species would have not been feasible. Instead, we represented classes of vegetation rather than individual species (e.g. reeds and elm- resembling models for the Bolečica riverside vegetation and for the area along the Danube, generic birch and oak models for hilltops and slopes, bushes for the forest undergrowth, and so on). Regarding classes of medium to large vegetation (bushes, trees, reeds etc.), free models for Blender Cycles are available for download, created by various digital artists whose only requirement is to be cited. Grass is presented using particle systems, which significantly add to hardware requirements but are irreplaceable when fine geometry needs to be shown.

Generic features that were to represent houses and other structures were modelled at the very end. This process relied mostly on the personal experience with the excavated Neolithic structures and their "projected" look. Also highly informative were relevant ethnographic sources and the repository of comparative remains of wattle-and-daub structures (particulary those available in 3D format). Our goal was to create the feeling of an ancient settlement, whilst avoid dealing with overly intricate details of house design for which there is no supporting material evidence. A pair of features (F01/06 and F03/03), of which one comprises a house floor and remarkably well preserved walls and an oven and, adjacent to this one, another feature of similar level of preservation, but different in size and internal structure, were reconstructed in Blender. This was done on the basis of photogrammetric models of the two features; we found this approach to be most productive as it made the entire process much more deliberate and intuitive. We also relied on a tentative reconstruction previously designed for feature F01/06 (Đuričić & Đorđević 2008). Several other features (e.g. benches, ovens, strewn animal skin, rubbish pits) were added in order to generate a more compelling impression of the settlement environment.

As a concluding remark, we would emphasise that the described process represents only one possible route; practitioners with different experience opt for different approaches, either concerning software or the concept. We would like to stress that, by and large, only a very constrained way of conducting similar projects will ignore the creative aspect of the process. Artistic drive can become overwhelming in the course of the work. This in no way should be seen as a flaw but, instead, as a welcome addition to the discussion of ancient communities. In virtual reconstruction, we project ourselves into past and bring about new readings of the material that we know so well and see so often.

Data acquisition – UAV survey

For collection of images, SenseFly eBee UAV was utilized. The total time needed to cover the area was less than 2 hours, and the photos were taken at midday.

- Camera type: CANON IXIUS 127 HS (geocoded photos - RGB)
- Covered surface: 1 km2
- Flight speed: 11-21 m/s
- Flight height: 100m (5cm/pix)

- Format: jpeg
- Total number of photos: 984
- Overlap: 70% / 70%
- Number of collected GCP: 7 (mean err: 1.5 cm) (Trimble R4)
- Figure 13 *Flight plan and trajectory of the drone used to acquire digital elevation model of Vinča Belo Brdo.*

(Contractor was tasked with full range of processing – production of orthophoto and DSM.)

Figure 13. Flight plan and trajectory of the drone used to acquire digital elevation model of Vinča Belo Brdo.
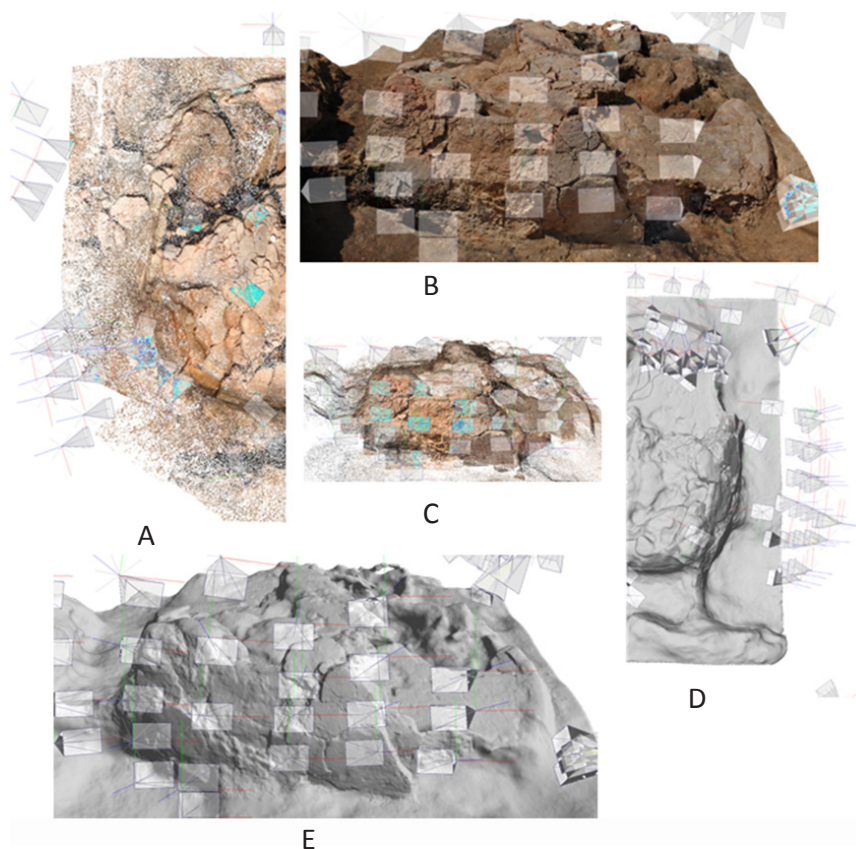
Figures 14 (A-E). Elements of photogrammetry used in producing virtual reconstruction of the kiln at the site of Vinča.

Figure 15. Virtual reconstruction of the latest horizons of Neolithic Vinča.

A COMPARISON OF DIFFERENT SOFTWARE SOLUTIONS FOR 3D MODELLING

Jiří Hrubý, Daniel Hlásek (TerraVerita), Zuzana Rejdovianová, Andrej Žitňan & Milan Horňák (Via Magna)

Autodesk ReCap 360

Autodesk ReCap 360 is a free online service provided by Autodesk Company. This software exists even as a standalone commercial version, with an optional trial/student version. Principally, the user uploads a 'photo-set' on Autodesk servers where all the data are processed and the user is subsequently informed via email about the process being completed. The use of this software is, in general, not recommended, as there are only limited possibilities to design the results. All possible options are presented on the project's start page. Besides the 'Project Name', it is possible to choose 'smart cropping' (allows to ignore areas 'behind' cameras) or 'smart capturing' (this option should improve resulting texture; it is currently in the beta-testing phase); measurement units are available only for "rcs" format (ReCap native format), but the final model can be viewed or downloaded in several other formats (obj, rcm, fbx, ipm, rcs and ortho). The service is limited to a maximum of 250 photos per task (based on ReCap1). Whilst the upload time is unavoidably influenced by the internet connection quality, the processing time cannot in any way be predicted. Usually it takes up to several hours, depending on the server connectivity, workload and the size of the photo-set.

For the presentation of the resulting 3D models created by ReCap 360, the CONPRA secondees prepared nine different models that were, in some cases, post-processed in Meshlab (Meshlab1). 'Model 1' was created from 99 photos of the 'Vinča set' (see chapter 'Data Acquisition'). The final textured result in "*.obj" takes up more than 1.1 GB of space and it is in any way fit to be used by 'ordinary computers'. The result includes a lot of gaps, probably
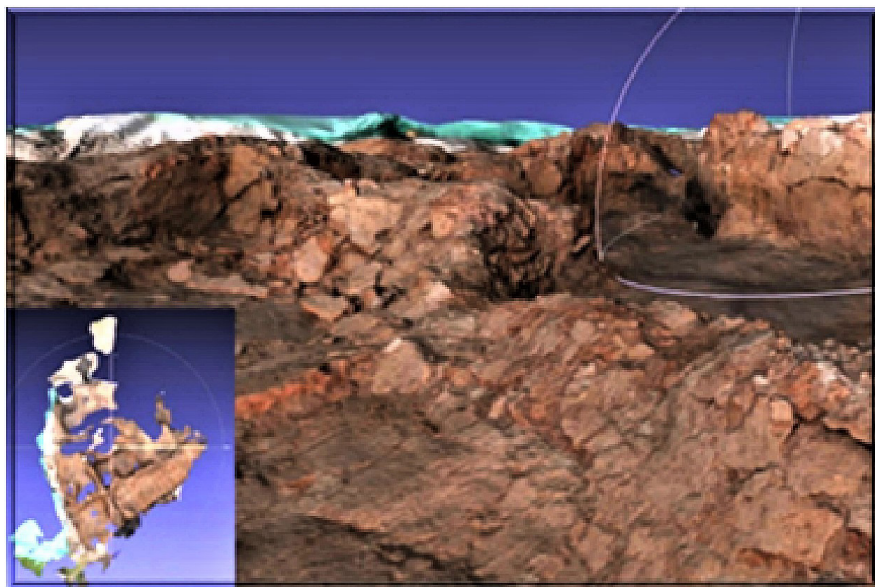
Figure 16. ReCap 360, Model 1 (photos by A. Žitňan, Via Magna).

due to the processing algorithms that were not able to stitch and properly reconstruct the dense point cloud and the final mesh. Figure 16 shows the preview exported from Mesh-lab. A detailed examination of result allows me to state that the final resolution and level of detail are satisfying, but errors in the model as a whole cannot be overlooked.

The next example is composed of 101 photos from the same photo-set and its size is about 1.05 GB. The model focuses on details of a Neolithic kiln and it can generally be observed that the result is much more satisfying when the redundant parts are removed in Meshlab. Nonetheless, the gaps still disrupt the result and render it unsatisfying and non-usable as, for example, a form of archaeological documentation (Figure 17).

The model presented on Figure 18 is composed of the entire photo-set (249 photos). It had the size of 1.53 GB before redundant parts were trimmed off. Unfortunately, such a large file was very difficult to process, so it confirms the impression that working with 3D models requires a powerful computer. The main parts of the model seem to be of relatively good quality and there are no gaps. Based on this, it can be concluded that the gaps in the previous two models were caused by the insufficient number of photos used, or an unsuitable photo-set. There was absolutely no problem in the service itself. But, the bad quality of the model outside the central parts of feature is another issue (see Figure 19).

'Models presented on Figure 20 are composed of 18 photographs (approx. 0.122 GB both) of original Roman tile photographed in the exhibition area of the Museum of Novi Sad. Because of the indoor light conditions, higher ISO values (1000) had to be used, so the photos are slightly disrupted by the high ISO noise. Nonetheless, this model can serve as an illustration of the differences between the automatic model creation and the use of the above-mentioned 'smart cropping' and 'smart capturing' options. It can be stated that, the model created with default settings came out without gaps in the texture and there is also no visible difference in the texture quality. Further, the 'smart cropping' option was of no importance.
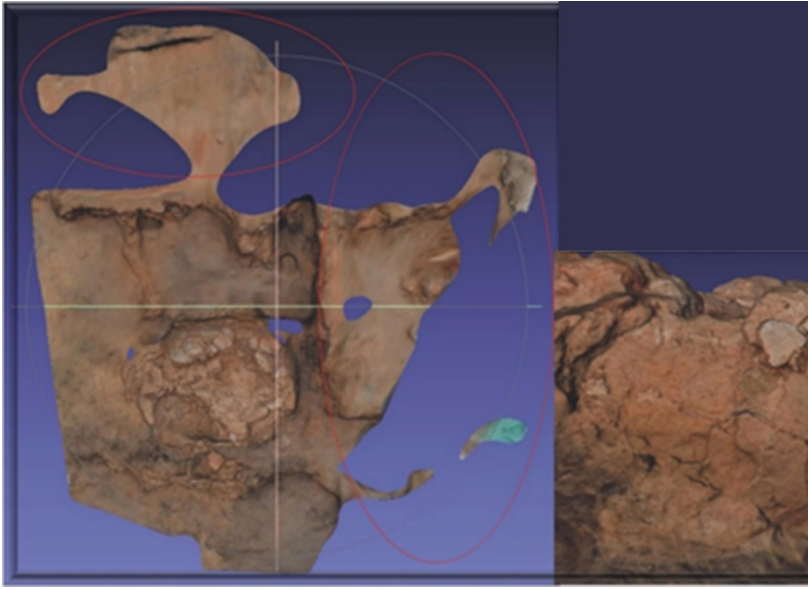
Figure 17. ReCap 360, Model 1 (photos by A. Žitňan, Via Magna)

Figure 21 shows model 6 (ca. 0.08 GB) which was sufficient to create a relatively good model and all errors and imperfections or deficiencies result from the input pictures. The blue background is inappropriate as it reflects blue undertone to the texture; moreover, it is too bold, so the service had to use blue texture as filling for the holes that represent missing potshards.

Figure 18. ReCap 360. Model 1 (original result; Photos by A. Žitňan (Via Magna).
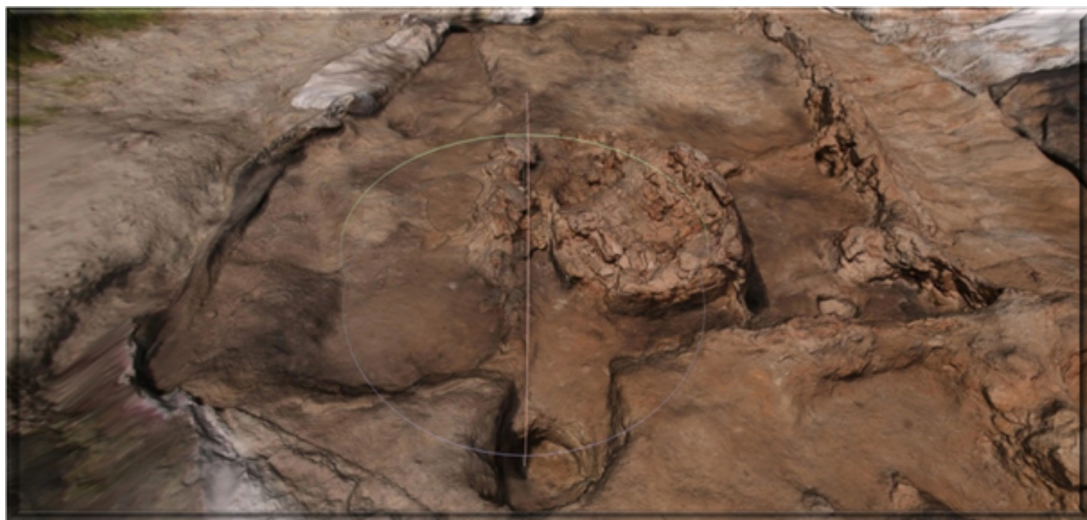
Figure 19. ReCap 360, Model 1; good quality central parts and bad quality of areas along the edges (e.g. lower left; photos by A. Žitňan, Via Magna).
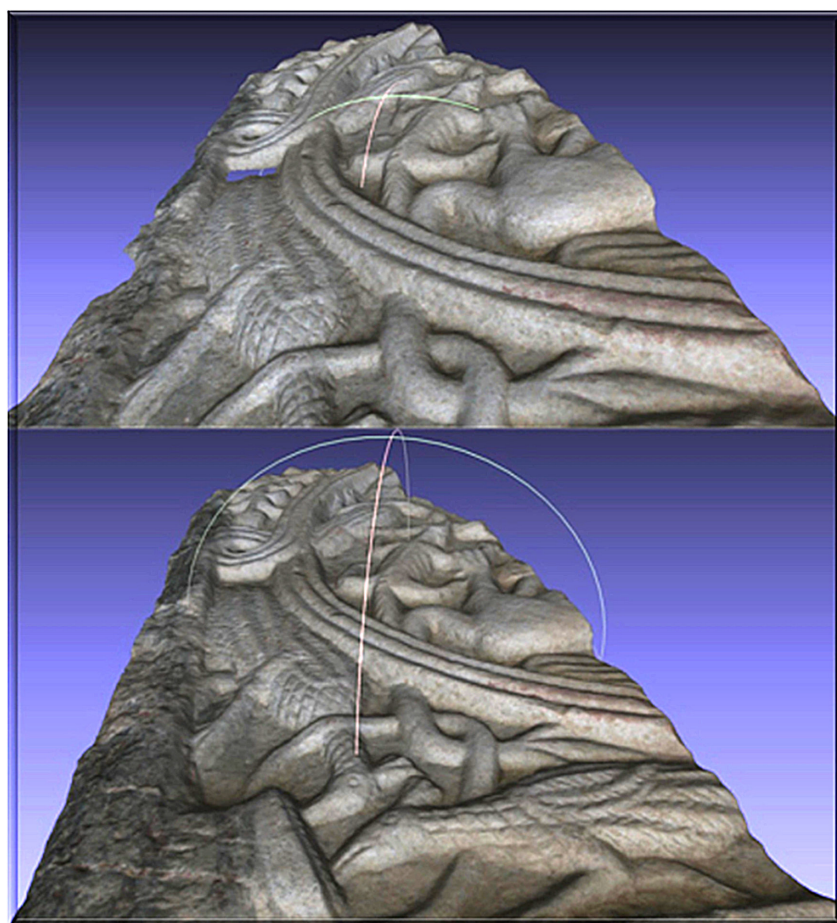
Figure 20. ReCap 360, Model 2; Roman relief tile (Museum of Novi sad); comparison of automatic/no adjustments (down) in recap 360 options and 'automated cropping' and 'smart capturing' option.
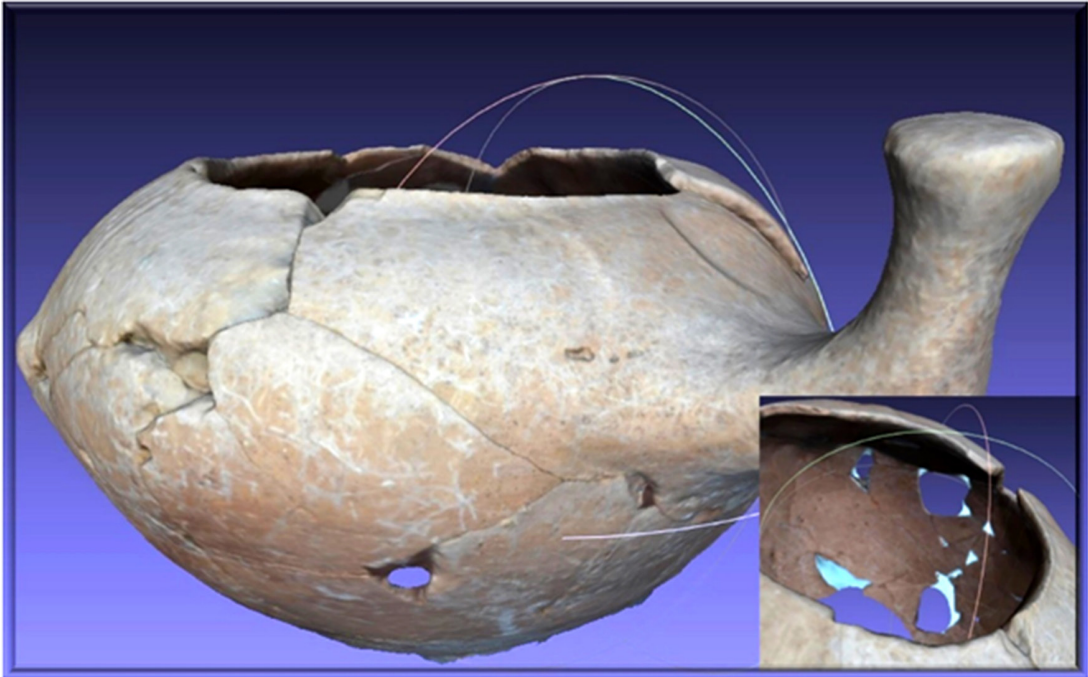
Figure 21. ReCap 360, Model 6 (photos by Z. Rejdovianová, Via Magna).

Figure 22. ReCap 360, Model 7 (photos by Z. Rejdovianová, Via Magna).

Figure 22 shows model 7 (another vessel from the Bronze Age Vinča) created from 49 photos. This model suffers from the same imperfections as the previous one. The miniature (lower right corner in the figure) proves the influence of bold blue background on the final texture. The texture imperfections are most certainly caused by the quality

of the photos. Also, it can sometimes happen that the input surface has not enough of alignment points (Figure 23).

Figure 23. An example of the input picture for model 7 with indicated problems and errors (photo by Z. Rejdovianová, Via Magna).

Figure 24. ReCap 360, Model 8 (texture detail; photo by Z. Rejdovianová, Via Magna).

The vessel (model 8) was created from 31 photos (0.056 GB) and is shown in Figure 24. This model is used merely for presentation purposes since it illustrates well the quality of texture that is possible to gain via the web service. The rest of the vessel (its inner parts) is not modelled well because of the blurred photos.

Summing up 'Autodesk ReCap 360 web-service', it can be stated that this is quite a useful service, able to provide quality outputs. This is, perhaps, not so evident in the presented examples, but the outputs are highly influenced by the quality of photos. The gaps in model 9 are the only errors which cannot be explained. Similar to the other considered services (see below), it requires fast internet connection, but the server response (the speed of modelling) is very satisfying (in that view, it does not differ from commercial or free standalone software).

Autodesk 123D Catch

Autodesk 123D Catch is a web-based service similar to the one described above. It offers creation of 3D models, their cloud storage and download; moreover, the commercial version enables direct 3D printing. In contrast to ReCap, this service is limited to 70 photographs per model (Windows version; 123DCatch).
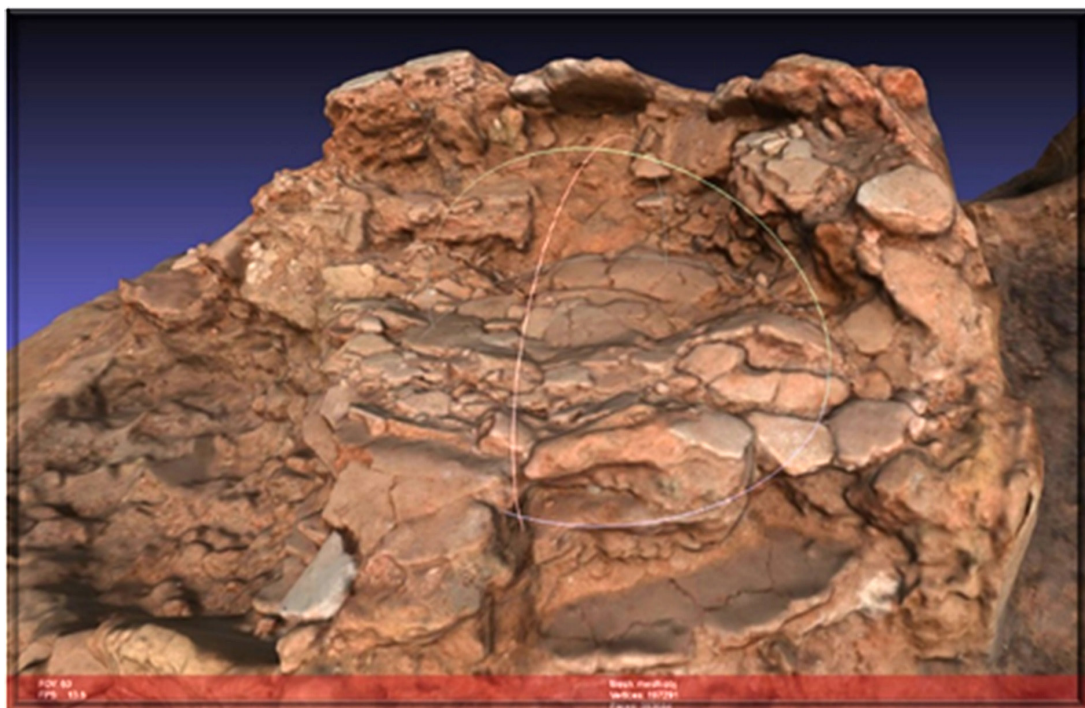
Figure 25. 123D Catch, Model 10 (photos by A. Žitňan).

Figure 26. 123D Catch, Model 11 (Roman tile and details).

The model labelled as model 10 was intended to use this service to produce a detail (kiln) using the 'Vinča site' photo-set (Figure 25). At first sight, there are no fundamental differences between this and the ReCap model, but, because of the service's limitation to 70 photos that can be used, it is not suitable for large models. Moreover, when zoomed-in to the maximum detail, it is clear that the texture detail is not high. Regardless of this, the mesh itself is useable.
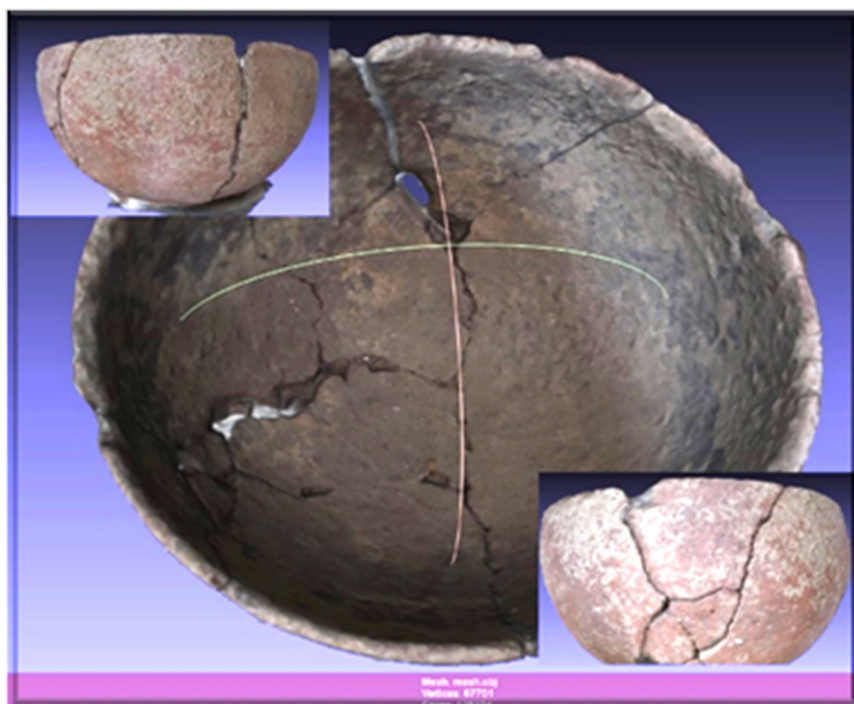
Figure 27. 123D Catch, Model 6, the Starčevo culture bowl.
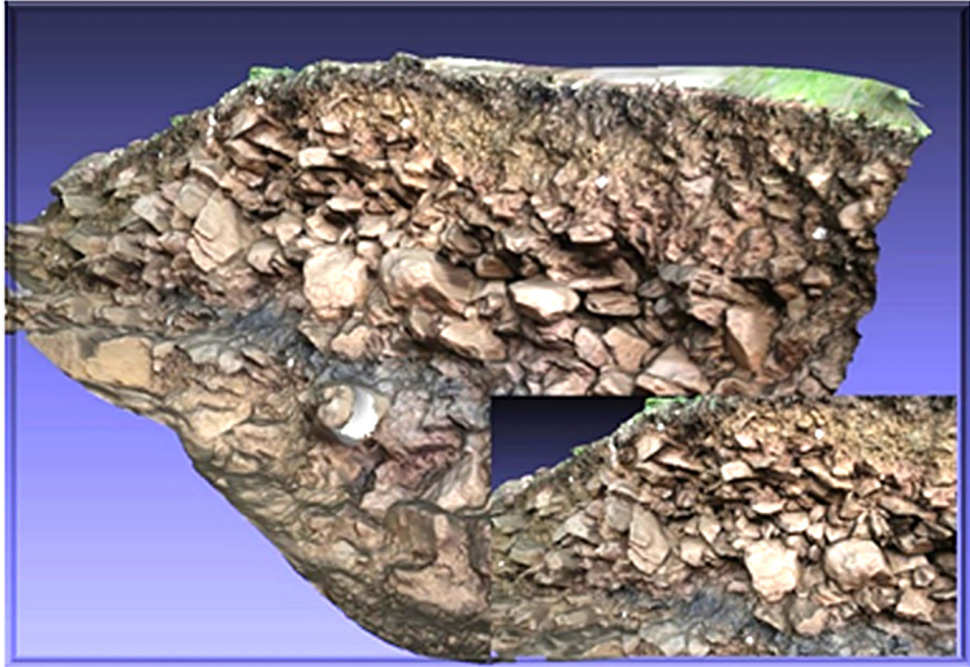
Figure 28. 123D Catch, Model 7, Vrcovice, trench (photos by D. Hlásek, TerraVerita).

Model 7 visualizes a trench profile from the site of Vrcovice (a hillfort in south Bohemia; ADC2010) and consists of 32 photos that were not initially created for 3D modelling (Figure 28). Nonetheless, the result is quite satisfying and presentable; the use of geo-referenced GCPs3 allows adding measurements, etc.

In conclusion, this application provides very good results for small features (e.g. artefacts, limited sections of the terrain). The important aspects are the service limitations: 70 pictures per photo-set and limited free download from Autodesk server (ten downloads per month).

Arc 3D 3 Ground Control Points

Arc 3D is a web-based group of tools allowing users to upload digital images to servers, where then a 3D reconstruction of the scene is performed. Similar to 123D Catch, there is a downloadable application. This application allows uploading and pre-processing of the pictures. The 3D reconstruction is based on the principle of auto-calibration, feature detection and correspondence, dense multi-stereo reconstruction and point cloud generation.

'ARC' has developed software to compute the reconstruction over a distributed network (cloud) of computers. This should make the procedure faster and more robust. Depending on the size, number and quality of the uploaded images, a typical job may take from 15 minutes to 2 or 3 hours (Arc 3D).
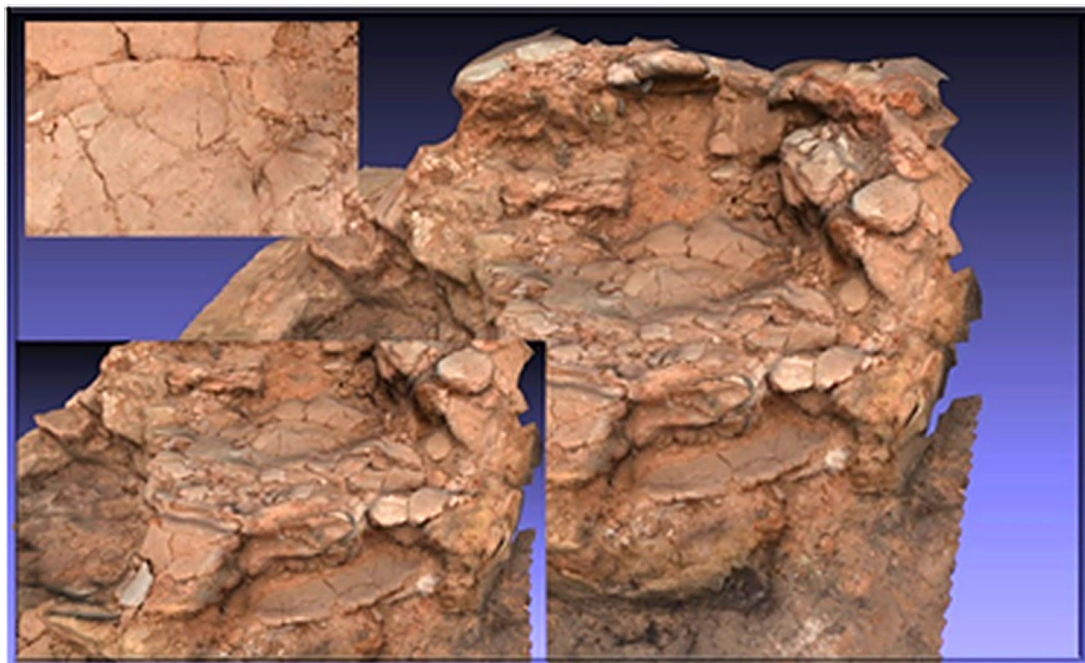
Figure 29. ARC 3D, Model 1 (photos by A. Žitňan, Via Magna).

Figure 30. ARC 3D, Model 2, Roman tile.

Figure 29 visualizes a detail of the Vinča kiln (0.035 GB). When compared against the 123D Catch result for the same kiln, Arc 3D provided more photo-realistic texture, but also more visible errors in places where the alignment and mesh reconstruction were not successful. The previously mentioned model of the Roman tile is of very bad quality (Figure 30). The team could not find a plausible explanation for the mesh and texture errors in this case. Similarly, model 7 from Vrcovice also came out with a lot of mesh and texture errors (Figure 31), but also with a very photo-realistic texture of significant

quality. These results do not rank Arc 3D high, although several successfully completed projects (not only archaeological) indicate the potential of this service. During the testing of the service, it was noted that it crashes frequently (for related information see Vergauwen, Van Gool 2006; Tingdahl, Van Gool 2011; Cignoni et. al. 2008).
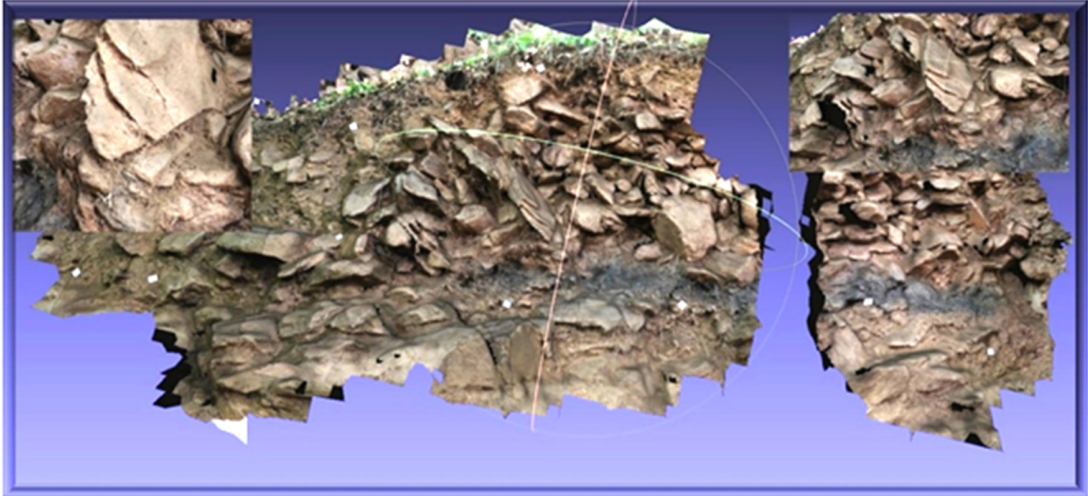
Figure 31. ARC 3D, Model 7 (photos by D. Hlásek, TerraVerita).

Standalone software solutions for 3D modelling

The following lines are devoted to standard software applications that are operational without the internet connection or secondary remote server services. An indisputable advantage is their self-sufficiency; on the other hand, they require powerful, high-end computer set that is able to run the whole process of 3D model creation (e.g. Photoscan2). Visual SfM (PMVS/CMVS) is a GUI application for 3D reconstruction using Structure from Motion.

The reconstruction system integrates several previous projects: SIFT on GPU (SiftGPU), Multicore Bundle Adjustment and Towards Linear-time Incremental Structure from Motion. Visual SfM runs fast by exploiting multicore parallelism for feature detection, feature matching, and bundle adjustment.

For a dense reconstruction, this program integrates the execution of Yasutaka Furukawa's PMVS/CMVS tool chain. The SfM output of Visual SfM works with several additional tools, including CMP-MVS by Michal Jancosek, MVE by Michael Goesele's research group, SURE by Mathias Rothermel and Konrad Wenzel, and MeshRecon by Zhuoliang Kang (VSfM1). In short, this open-source software package provides first steps of '3D-model creation': alignment, sparse and dense point cloud (with CMVS/PMVS extension; VSfM2) and computing. The subsequent steps must be carried out using Meshlab and Blender software (mesh and textured model). The first example shown here visualizes a trench profile from the site of Vrcovice as a compiled orthogonal photo (ICE1) with a final dense point cloud in the upper left corner (Figure 32). Figure 24 shows the reconstructed

'sparse cloud' from one of the vessel photo-sets (composed of 67 photographs). The other examples created from photo-sets of different size (49 and 31 photographs) are visualized in Figures 33, 34 and 355. The exemplary process is visually demonstrated in the following figures and accompanying text .
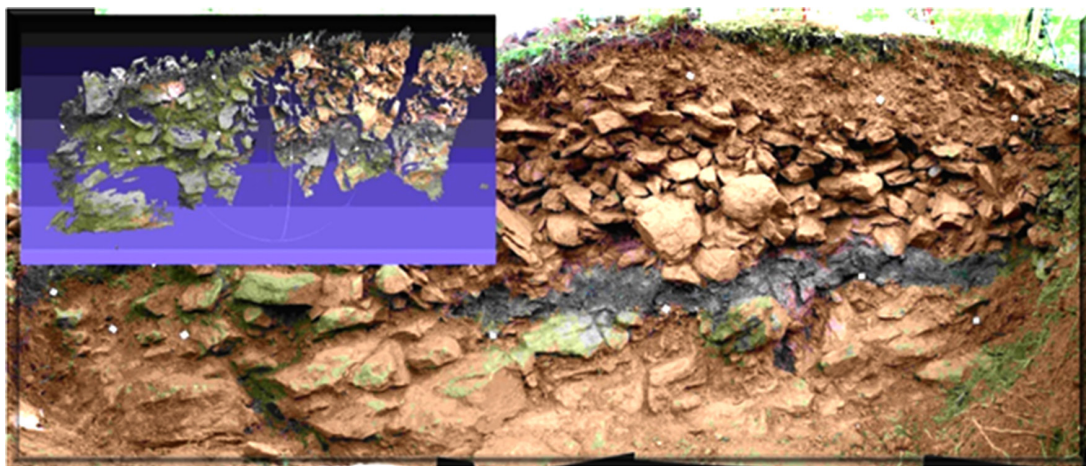
Figure 32. 'Ice' and 'Visual structure-from-motion', Model 7 (photos by D. Hlásek, TerraVerita).

The team has attempted to create a 'cost-free' model from the available set of photographs of the 'Roman relief tile'. The first step was the creation of 'sparse cloud' from the original photographs using Visual SfM. Then, the resulting 'sparse point cloud' was transformed into 'dense point cloud' using CMVS/PMVS algorithms of Visual SfM. Until this stage it was possible to work with Visual SfM GUI. Unfortunately, this software is not capable of creating 'meshes' from 'dense point clouds', so it was necessary to use another open source program – Meshlab. In summary, one has to import 'sparse and dense point clouds', create 'Poisson Mesh Surface' and 'parametrise' previously prepared pictures (during CMVS/PMVS procedure) to create the texture.

Figure 33. Visual SFM (sparse cloud), Model 4 (photos by Z. Rejdovianová, Via Magna).

Figure 34. Visual SFM (sparse cloud), Model 5 (photos by Z. Rejdovianová, Via Magna).
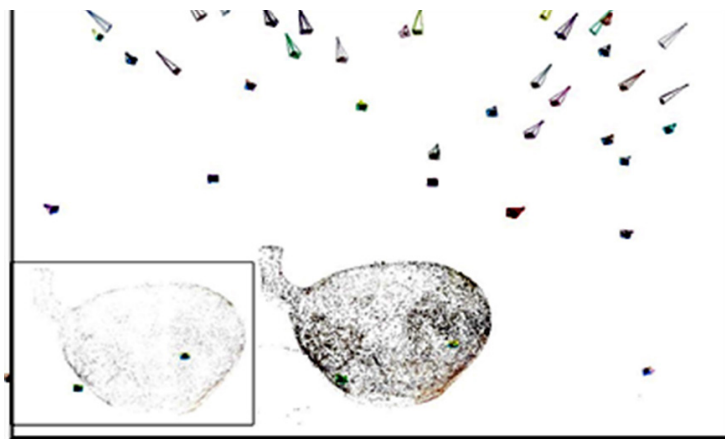
Figure 35. Visual SFM (sparse cloud), Model 3 with camera positions and a detail of the sparse cloud point model; photos by Z. Rejdovianová, Via Magna).

Figure 36 shows the final mesh surface that is based on 'dense point cloud' created by Visual SfM and Figure 29 visualizes the following step, i.e. the parametrized texture over the mesh. The models created with Agisoft Photoscan and presented here (see relevant figures) used the legal version of the software (provided by A. Žitňan, Via Magna) or a 30-day registered trial version (Photoscan). There is no need for an in-depth analysis of this software since it has been discussed before, including examination of its application in archaeology (e. g. Plets et al. 2012; Sapirstein 2014; Thanaphattarapornchai 2012).

During the CONPRA secondments, the team created several models using this software which I comment on here. Figure 37 shows a high-quality mesh model of the Vinča site; the pictures that follow present the medium- and low-quality models in order to high-light different results produced under different software settings (Figures 37,38). 'Model 1' is shown once again in Figure 39, where only 'sparse point cloud' was used as a base for computing the mesh and the texture. At a first sight, it is clear that the final textured model is not of good visual quality, but it seems that this 'shortened' procedure may be suitable for less detailed or flat features (details of the site are visualized in Figures 40, 41).

Figure 36. Meshlab (mesh), Model 2 created by Visual SFM (dense point cloud) and Meshlab (mesh).

Just as a comparison with the previously mentioned software, Figure 28 shows a model of the Vrcovice trench profile. Further features that the team has tried to create 3D models for are artefacts: the Roman tile – 'model 2' and the Vinča vessels – 'models 3-5'. and so on. Figure 44 visualizes a detailed overview of the Roman tile and the relief; it is characterized by a high level of relief details and texture. Figure 43 shows one of the Vatin culture vessels from Vinča. The model suffers from the same errors noted and discussed for models shown in Figures 8, 9. The need for high-quality photographs
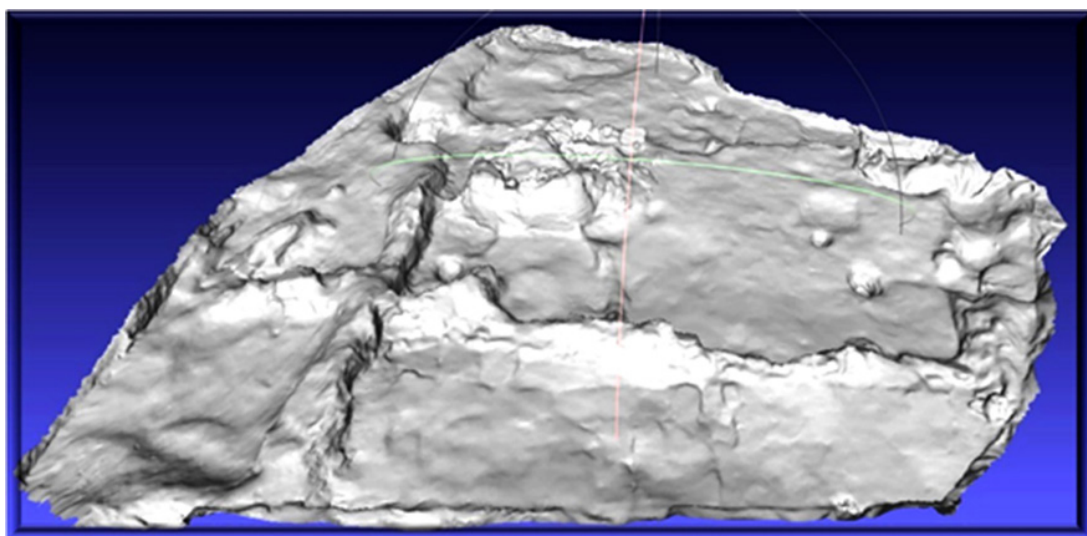
Figure 37. Agisoft Photoscan, Model 1 (low quality; photos by A. Žitňan, Via Magna).

and their pre-processing is illustrated in Figure 39. The 'Vinča mask' model is character-ized by quality mesh and texture; moreover, the pre-processed photographs resulted in a clear model without disturbing elements of the background (46 Cameras/46 aligned (cropped); 35285 tie points; dense cloud 24 169 280 points; 3D model 4 861 512 faces). The same result is shown in Figure 45. Figure 46 shows in detail the aligned inner and outer surface of 'model 5'; it was possible to create the whole model (model, surface chunks alignment etc.) using a single software.
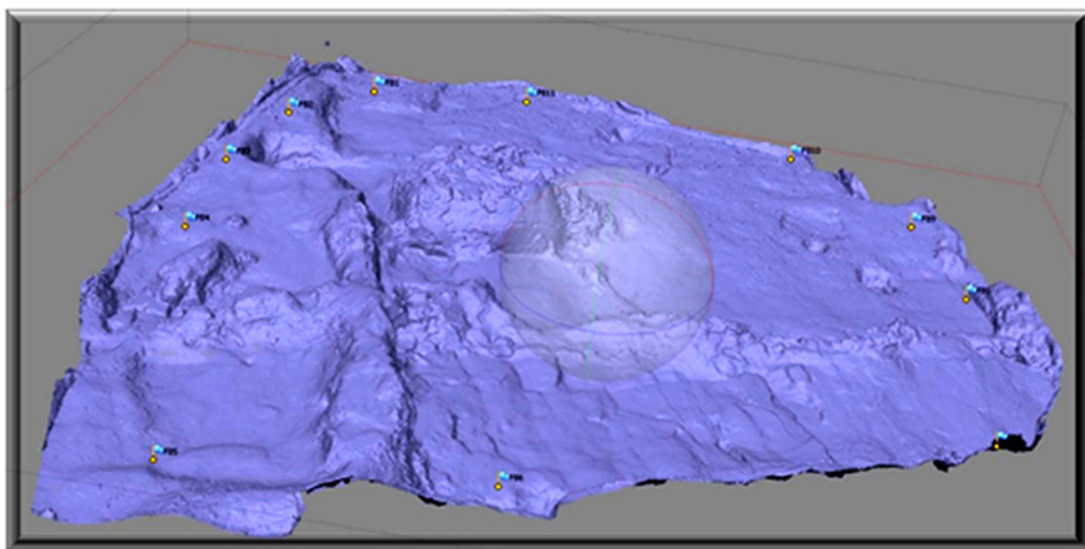
Figure 38. Agisoft Photoscan, Model 1 (medium quality; photos by A. Žitňan, Via Magna) with 'GCPS'.
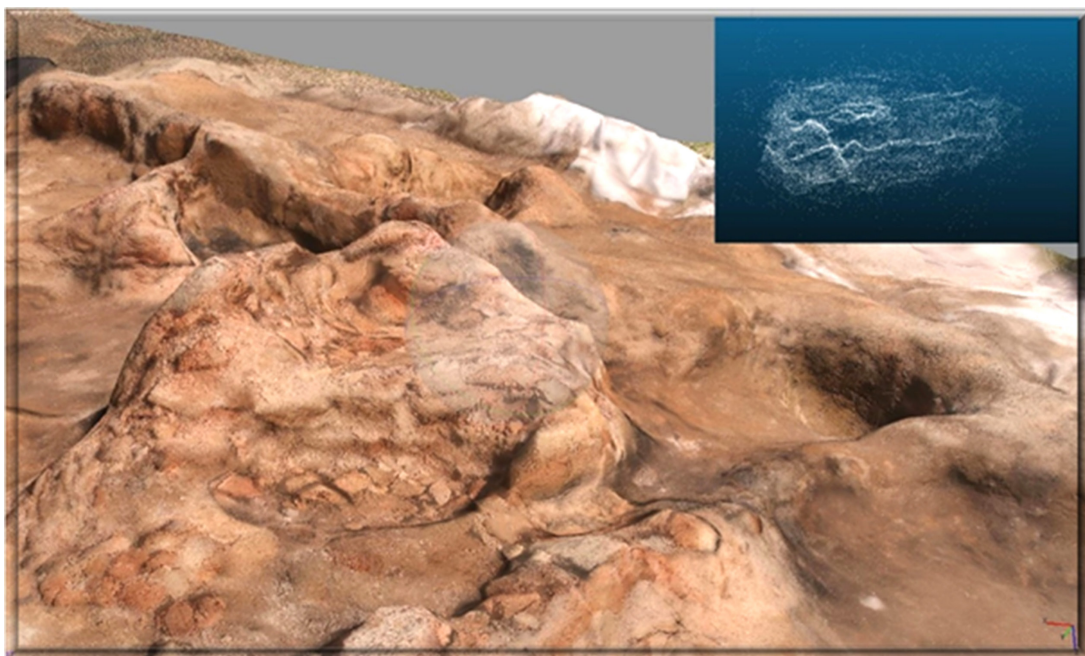
Figure 39. Agisoft Photoscan, Model 1 (model based on sparse point cloud;
photos by A. Žitňan, Via Magna).
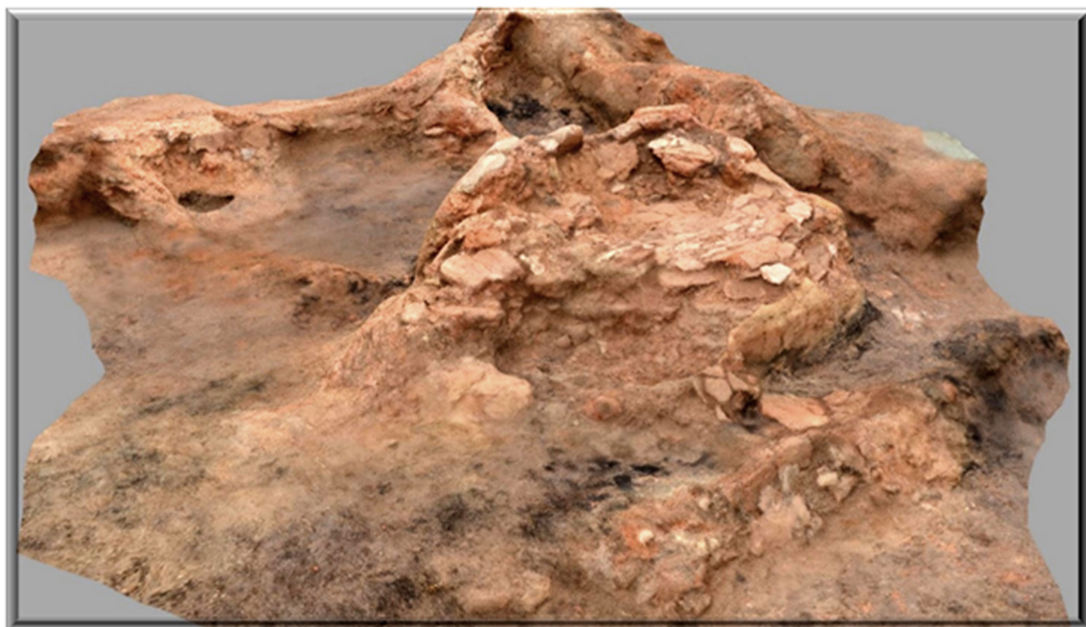
*Figure 40. Agisoft Photoscan, Model 1 (detail of a kiln; low quality settings;
photos by A. Žitňan, Via Magna).*

*Figure 41. Agisoft Photoscan, Model 1 (detail of a kiln; medium quality settings;
photos by A. Žitňan, Via Magna).*
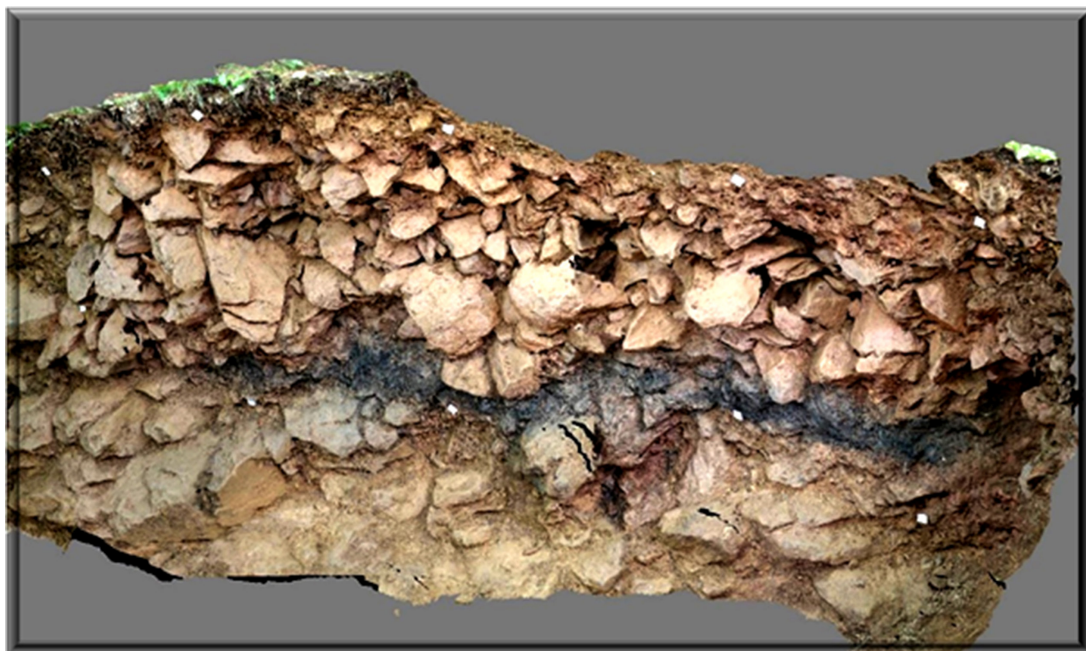
Figure 42. Agisoft Photoscan, Model 7 (photos by D. Hlásek, TerraVerita).

Figure 43. Agisoft Photoscan, Model 4 (photos by Z. Rejdovianová, Via Magna).

Figure 44. Agisoft Photoscan, Model 2.
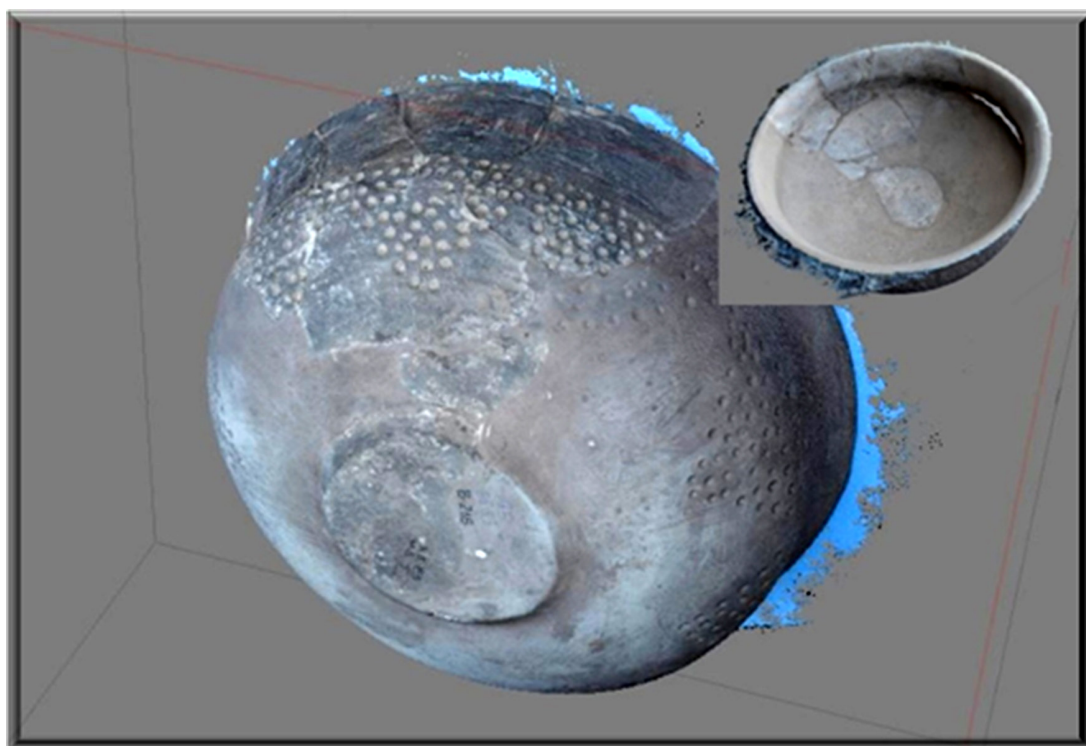
Figure 45. Agisoft Photoscan, Model 5 (photos by Z. Rejdovianová, Via Magna).

Figure 46. Agisoft Photoscan, Model 9 (photos by Z. Rejdovianová, Via Magna).

Software comparison: Conclusion

In general, it can be concluded that it is possible to use 'commercial' or 'open-source' software in the same manner. Both routes are capable of producing satisfying results. However, it is first necessary to obtain high-quality input photographs; it is also crucial to use high-end computer to reduce the processing time (regardless of the type of software used). Commercial software, like Agisoft Photoscan, is a powerful tool capable of conducting all of the steps in a single place (including geo-referencing), but the software must be purchased. Nonetheless, it is a well-suited and solution worth-investing in for professional use (even in archaeology). Open-source software is also useful. In this case, it is usually necessary to use some specific software solutions and one has to be prepared for frequent software crash and incompatibilities with some graphic cards (e.g. the tested software worked well on a powerful PC, but when a notebook used, the software kept crashing whilst importing dense clouds into Meshlab). There are a lot of possible reasons for this ill-performance which then hamper the work progress.

In sum, one option is to invest in professional software and be able to work without facing recurring problems, and the other is to invest time to test and learn the best way of operating open-source software. It is, ultimately, a question of how much time/funds one can set aside for this type of work and what outcomes are expected/satisfactory. It is our opinion is that the commercial software generates better results mainly in the last stage, i.e. the visual texture quality; as regards 'point clouds' and 'mesh' creating, both types of software give similar results.

EXAMPLES OF GOOD PRACTICE IN 3D VISUALISATION IN PREVENTIVE ARCHAEOLOGY

Milan Horňák (Via Magna)

Archaeological visualisations focused on the analysis of results of field excavations have been considerably improved by development of digital and IT technologies. New technology did not provide faster, more accurate and efficient modes of data recording and processing, but instead opened a series of new conceptual questions regarding the study of past architectures and the possibilities of presentation of the results of archaeological excavation to the public. It should be emphasised that, 3D reconstructions help develop the protection of archaeological monuments, they help promote the work of archaeologists, and they directly influence cultural heritage awareness of a population, which is the most important aspect of the preventive protection of cultural heritage. From the perspective of preventive archaeology, it is also a very efficient tool that can add a significant scientific value to research results, as this aspect is almost absent in the process of rescue research.

One of the aims of the project EU FP7 MARIE CURIE ACTION IAPP "CONPRA – Contributing the preventive archaeology: Innovativeness, development and presentation", the results of which are presented in this monograph, was to introduce methods and possibilities of 3D visualisation, with emphasis on the education of variously qualified archaeologists active in the process of preventive archaeology. I here present examples of good practice in the application of 3D visualisation in archaeology.

Scientific principles of 3D virtual reconstructions

The input for 3D reconstructions created by our company consisted of data obtained from various rescue archaeological investigations (e.g. the northern terrace of the Bratislava Castle, Bratislava, the medieval monastery Skalka nad Váhom and the settlement from the Late Bronze Age in Rajec-Charubiná; Figure 47) in which the author of this article acted as the head of research and which were performed by the company Via Magna s.r.o. – a partner institution in the CONPRA project. The archaeological data were collected in said excavations by applying the methods of 3D photogrammetry so as to allow creation of the geo-referenced photograms in the program Agisoft software-Photo Scan Professional and Capture reality. The photograms subsequently served as the direct input for reconstruction, modelling and visualisation of the investigated masonry architecture from the La Tène culture (European Iron Age) and the Middle Ages, or archaeological structures from the Late Bronze Age. The programs SketchUpPro and Cinema 4D were used as the basic analytic tool for 3D models.
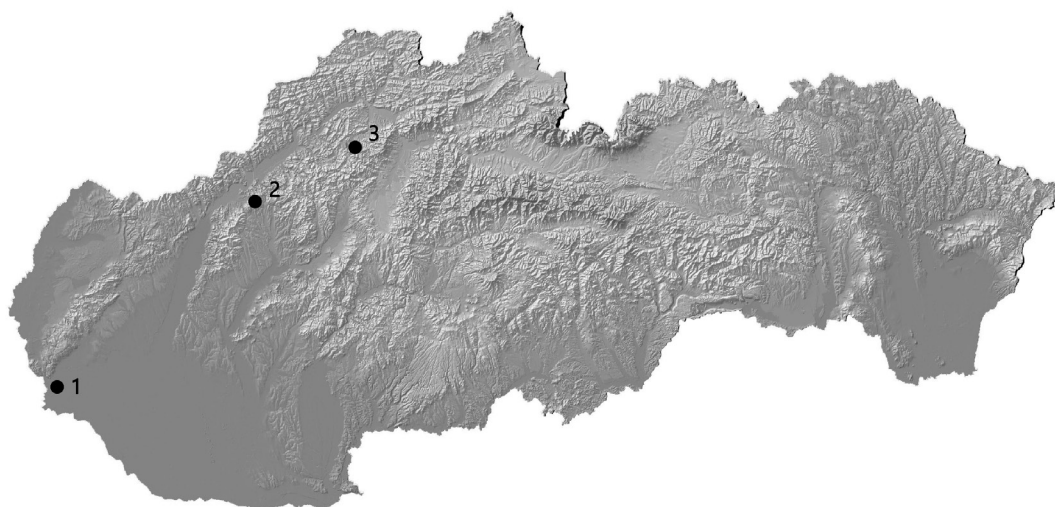
Figure 47. 3D visualisations of archaeological/architectural sites: 1. Bratislava;
2. Skalka nad Váhom, Trenčín; 3. Charubiná, Rajec

VR of a Celto-Roman building, Bratislava Castle, Bratislava, Slovakia

During the archaeological research of the northern terrace of the Bratislava Castle in 2013-2014, directed by the author of this article, a unique masonry building which was, according to the related finds, dated to the 1st century B.C., was reinvestigated. It was the best-preserved building of the acropolis of the Late La Tène (Celtic) oppidum. We named it "the building with eights pillars". The name reflects the fact that this was the only structure with almost completely preserved ground floor and walls on each side.

However, the building was damaged, especially in the Early and High Middle Ages, with the Baroque period constructions. The damage includes quarrying of stone walls down to the foundation level, truncation of the original floor and dismantlement of one of the pillar stands. The walls were preserved up to the height of 50 cm. The pillars were placed on rectangular sandstone slabs the dimensions of which were 52x54 cm. Still discernible at the time of the excavation were central crosses; also, a circle of 43 cm in diameter was visible on two of the slabs. No complete, or parts of, worked stone pointing to the presence of some other architectural elements were found. We assume, on the grounds of the revealed layout, that this was an atrium building, similar to the ancient atriums in buildings of the Classical world in the Apennine Peninsula.

3D reconstruction was created using SketchUpPro software. The basis for the modelling was the 3D photogrammetric model made during the archaeological excavation (Fig. 48).

Figure 48. Ground plan of the Celto-Roman building II, the basis for the 3D reconstruction.

In creating this 3D reconstruction, we started from a theoretical hypothesis that emulation of Roman buildings in Celtic environment was a symbolic demonstration of the influence of Celtic rulers of the Bratislava oppidum. However, we were aware that the "replica" of a piece of Roman architecture located in the different climate likely had a different meaning and functional than in the country south of the Alps. We know from the literature that columns were used by the Romans only for atrium buildings. The reconstruction itself was performed by gradual layering of individual architectonic elements into the logical structure, and subsequent rendering of colours (Figure 49 a-e):
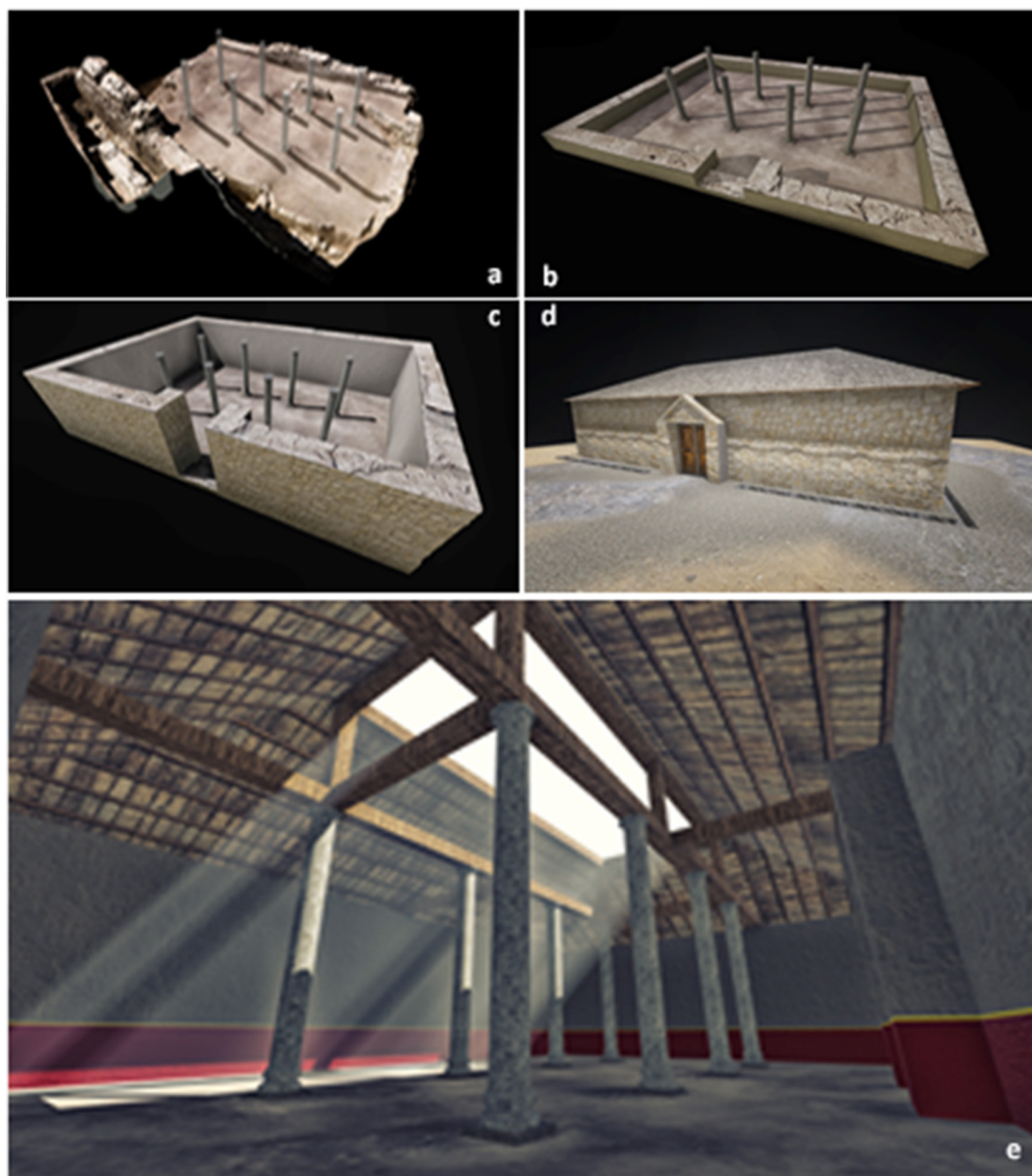
Figure 49 (A-E). Sequential modelling of the reconstruction of the Celto-Roman building II.

Medieval monastery Skalka nad Váhom, Trenčín, Slovakia

According to generally accepted interpretation, the Benedictine abbey was founded in the area of "Villa Scala" by the Nitra bishop Jacob I in 1224. This foundation allegedly happened at the cave popularly named "Skala" which, in the 11th century, was a place where, according to the Maurus legend, saints Andrej-Svorad and Benedict resided. The monastery was taken over by the order of Jesuits in 1644 who completely renovated the

monastery in the period 1667-1669. Further building modifications were made in 1712-1713, when both the small church and the monastery were renovated in the aftermath of the Kuruc wars. A new kitchen was built then and a few rooms added. The large hall was turned into a refectory, which was paved with square stones and illuminated from three sides with large windows. New windows were also installed, new chimneys built and the tiled roof repaired. In 1768, all monastery buildings got new roofs. After the Jesuit order was disassembled, the abbey property was transferred to the state ownership. he property was received by the Study Fund in 1780 and the monastery administration was assigned to the Skalka parish. The overall appearance of the monastery in this period is captured in an important iconographic source, providing the general ground plan, the layout of individual floors, as well as views of the facades; this source served as a basis for our 3D reconstruction.

Figure 50: Baroque depiction of the monastery from 1783 (A), suggested model (B).

3D reconstruction was created using SketchUpPro software. The basis for the modelling was a historical depiction of the monastery in its baroque development phase (Figure 50) and the 3D photogrammetric model of its present condition (Figure 51). The process of the 3D reconstruction is shown in Figures 52 A-E).

Figure 51. View of the current state of virtual reconstruction.
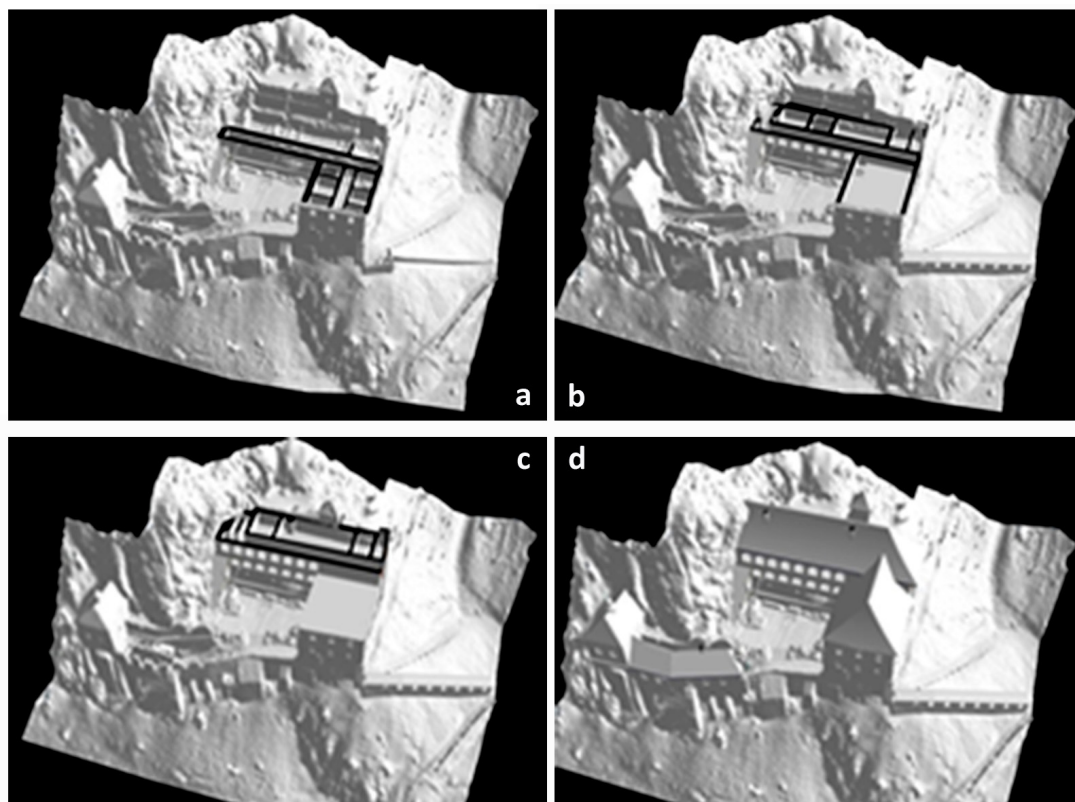
Figure 52. (A-E) step by step modelling of the baroque phase of the monastery.

The last step was colour rendering

Figure 53. Final 3D reconstruction of the baroque phase of the monastery (M. Hornak).

Late Bronze Age settlement in Charubiná, Rajec, Slovakia

The archaeological research is currently associated mainly with building investment actions, and such research must be performed prior to the start of construction works in

line with the relevant legislation. In compliance with the legislation, rescue investigation was performed in March 2016 in the area of planned expansion of the existing local golf courses. A settlement from the Late Bronze Age (1000-700 B.C.), built by Lusatian culture community, was excavated.

The dominant section of the examined location consisted of settlement structures. It was established that the structures were dug into clay subsoil. They were of irregular circular shape at the level at which they were identified. We here focus on those of the structures that allowed us to understand the life in this prehistoric settlement and that provided sufficient input data for 3D reconstructions.

Destruction of a prehistoric hut: After the removal of topsoil, partially preserved house foundations were recognized in the field (Figure 54 a) consisting of floors with distinctive layer of red colour containing high concentration of screed and ceramics (Figure 54 b). On the grounds of the interpretation of screed as a structural component of the building, we assumed that the remains represent a destroyed wall. Clay floor was preserved in the interior of the house; on top of it, a significant concentration of pottery fragments and traces of several fireplaces were found. A drainage gutter was probably dug around the house, of which parts were preserved to the south-east and north-west of the house foundations.

Figures 54 A, B. (A) Remains of the house – clay floor with the concentration of potshards.
(B) Detail of the concentration of pottery fragments.

Cooking pit: The examined feature, which was interpreted as a cooking pit based on its contents and the appearance, was situated approximately 7 m southwards from the above-described house. The excavation area enclosed the destroyed house and its depth was subsequently extended to include the detected cooking area. The cooking area was filled with burnt stones, which were placed into the pit to provide sufficient heat whether for heating of water or for slow cooking of meat-based meals.

Structural complex No. 3: A group of settlement structures was situated in the lower western part of the examined area. It was interpreted as a "working area" of the described house. Its main axis overlaps with the drainage gutter, which probably started nearby the house. It could be established that all of the registered remains were preserved thanks to this drainage from the Late Bronze Age, as the drainage of the slope

prevented erosion, which would have been caused by rain flow being retained on top of the impermeable clay subsoil. The gutter was filled with soil containing large quantities of pottery and house rubble. A distinctive accumulation of pottery was found around the gutter – remains of whole but broken pots. These deposits were most likely associated with the use of the house.

The data gathered by secondees A. Ðuričić and N. Jončić during the rescue excavations using Cinema 4D software. We have relied on the available knowledge as a starting point, considered also the current problems when attempting a reconstruction of pre-historic dwellings.
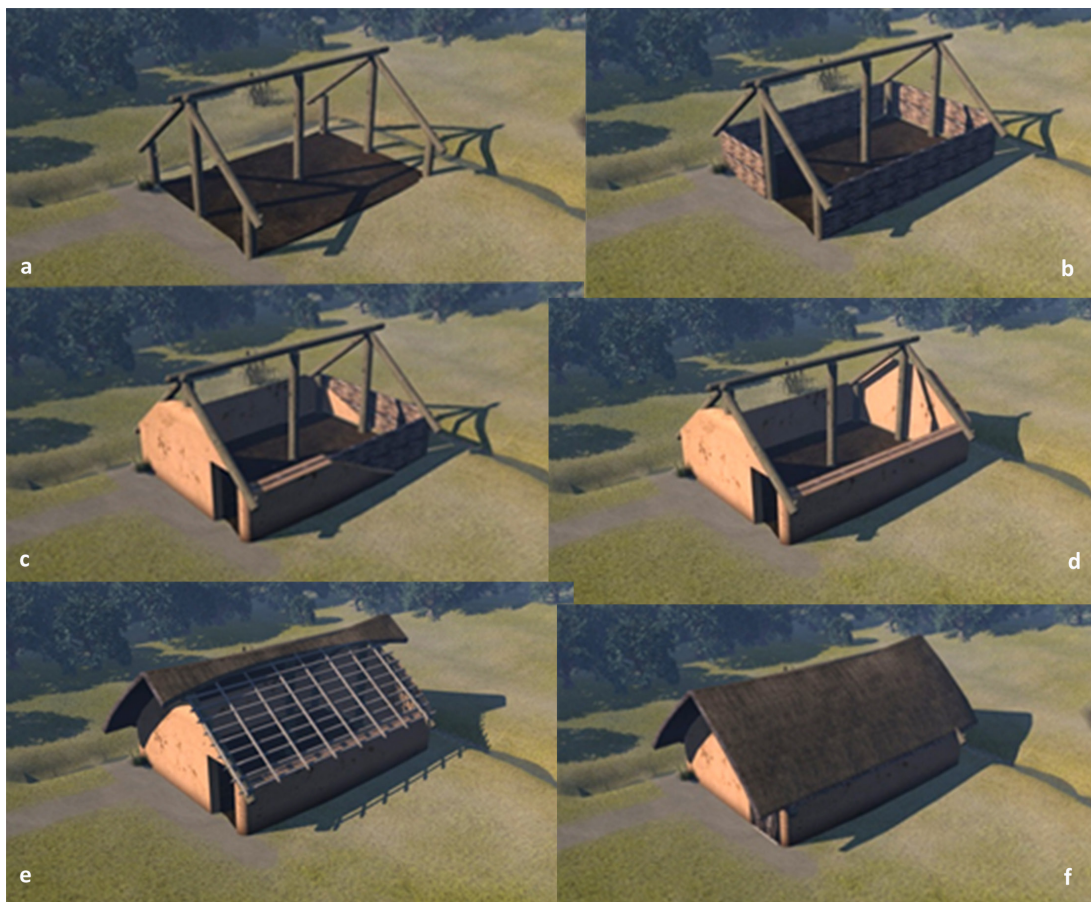
Figure 55. Stages in modelling of the reconstruction of the Late Bronze Age dwelling

Conclusion – Different ways of presenting 3D virtual reconstructions

In conclusion, we would like to present experiences gained during the creation of the described 3D models.

Quality of the input data: Data obtained through field and archive research must be se-lected prior to the 3D reconstruction itself. Such data should allow extracting specifically

the descriptions of individual construction stages, structural elements and function(s) of the structure. Thanks to the fact that large quantities of data are accumulated during archaeological investigation, it is possible to use them for 3D reconstruction already during the research. If we wish to place the model in space, we need to work with geo-referenced data. For this purpose, geo-referenced photographs of the layout of architectural elements or distribution of artefacts appeared to be the best source.

Selection of software and cooperation with IT specialists: Selection of suitable software is an important aspect in 3D reconstruction in archaeology. The current market offers various fee-based or open-access programs. We decided to use programs SketchUp Pro and Cinema 4D, as those were part of the program portfolio of the Centre for Digital Archaeology, University of Belgrade. The user interface of both programs is generally user-friendly, but based on personal experience and the demands placed by software on the archaeologist working in preventive archaeology (e.g. the requirement to be able to work in graphic and geodetic programs), I would recommend cooperation with experienced IT experts, as the training in the use of new programs requires considerable time and previous knowledge.

Methods of presentation to the public: From the perspective of a common user, we can, in principle, display results of the 3D reconstructions in several open-source programs that allow various presentation properties. First, we used Adobe Reader interface (PDF). This format proved to be more-or-less adequate, but it has problems with imaging, it jams and can rotate the model only about one axis. We then tried SketchUp environment. The results were similar to those obtained in Adobe Reader. The third method was to create a classic video (in AVU or MP4 format). This method proved as very efficient because of its easy access, fast loading and granted complexity of the information that we want to pass on through 3D reconstructions. This last method was displayed by means of QR codes (various models); it is very impressive, but it requires additional time and cost for programming some specific applications.

AUGMENTED REALITY AS AN OUTPUT

Nenad. N. Tasić (University of Belgrade)

Augmented reality will probably be the medium which will, in the near future, be used to communicate with the largest part of the general public. This phenomenon is already gathering the momentum. There are already dozens and dozens of apps designed for smart phones which present archaeological knowledge. If you browse Android market, you can currently find numerous archaeological tourist guides, archaeology news, games, tutorials and field aids.
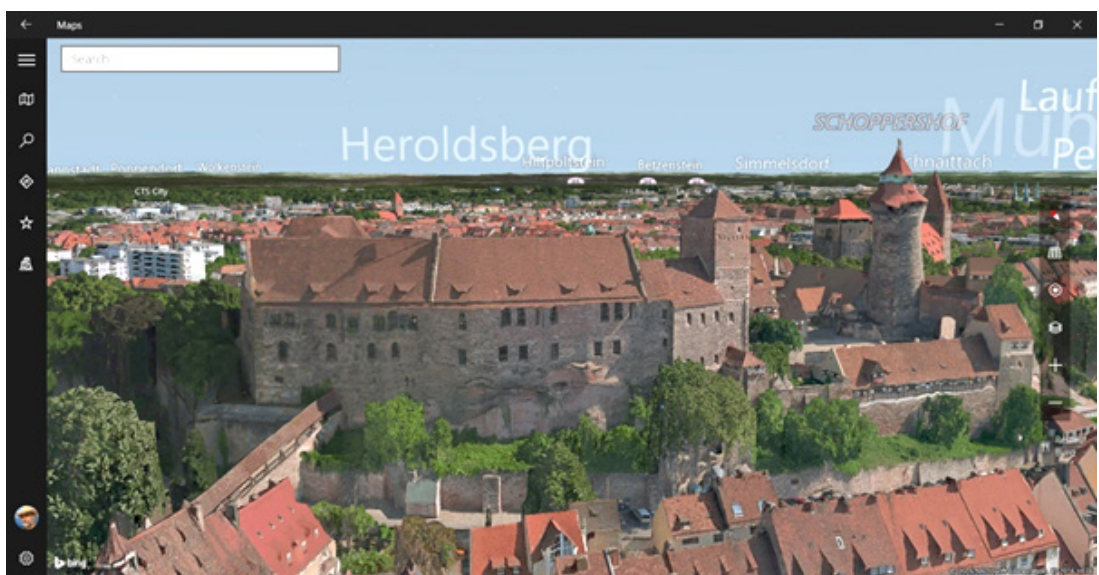
Figure 56. A screen from Bing maps showing simple AR

However, it seems that we are yet see a market which will fully exploit endless possibilities of the concept of Augmented Reality. There were some attempts even in Belgrade, Serbia and the one named 'Muzzeum project' is closest to mind, because it was pursued by the same IT expert who, in 2003, co-designed ArchaeoPack with the author of these lines and who managed the technical part of the 2004 edition of the virtual reconstruction of 15th-century Belgrade. The Muzzeum project was conceived and realized by V. Jevremović, who has tried to draw attention of the general public to the fact that, at the time (in 2012), Belgrade did not have a single operational museum where a member of the general public could observe archaeological artefacts and other finds. It was the time, and still is today, when the National Museum in Belgrade was closed (since 2002) and its opulent collections were stashed away in depots. The result of the Muzzeum project was augmented reality software triggered by QR codes as activation fields. QR codes were printed and displayed on the walls of the National Museum in Belgrade and 3D models of some important artefacts kept in the dark museum store rooms appeared on screens of smart phones or tablets when these were placed in front of them. However politically naïve and futile this attempt was in its demand to finally open the Museum for the public, it demonstrated one of many opportunities this concept offers for the heritage popularization. To hold up a device in front of a QR code and obtain archaeological content, or see a live image when the built-in camera is placed in front of archaeological drawings, 3D reconstructions etc. (such as in unusually interesting app SkyView) would be extremely suitable for otherwise static and silent archaeological finds that are important, but apparently unattractive. From my experience in the capacity of a tourist guide at the site of Vinča, which is an extremely important Neolithic site composed of almost 10 meters of cultural deposit, what the public needs are reconstructions. Apart from the fantastic view of the Danube and a small museum where one can see artefacts unearthed at the site, the auditorium is offered very little in the way of sensing the place as it was in the Neolithic. And instead of building replicas at this legally protected, multi-layered site, Augmented Reality could bring forward 3D models of individual architectural structures and even provide a walkthrough the Neolithic village from 5000 BC. Introduction of more of the available VR devices would certainly bring life to the site and make the visit to the site unforgettable.

Another possible use of AR is related to non-virtual reconstructions of architectural structures such as churches, castles, towns… In these cases 3D models could overlap with the actual structures and show their potential building and destruction phases that date from different periods.

I believe that a rule is still in place that requires one to carry out the reconstruction of a structure in a way that demonstrates the distinction between the original and the reconstructed parts (by using different colour or different building material). However, this rule tends to be avoided or at least bent when reconstructing structures such as castles shown here in Figures 3. Here, as well at many other places, the "educated guesses" of experts and "experts" applied for the reconstructed parts are presented as original elements of the structure. The use of AR would enable the visitor of the site to place their camera in front of the reconstructed structure and trigger layers which would, eventually, produce an image of the original state of the structure and show its history. Different colour shades could indicate different building phases of the structure. The visitor could also be shown the analogies used in the reconstruction of the structure. In such a way, VR could re-instate the "reversibility" of physical reconstructions.
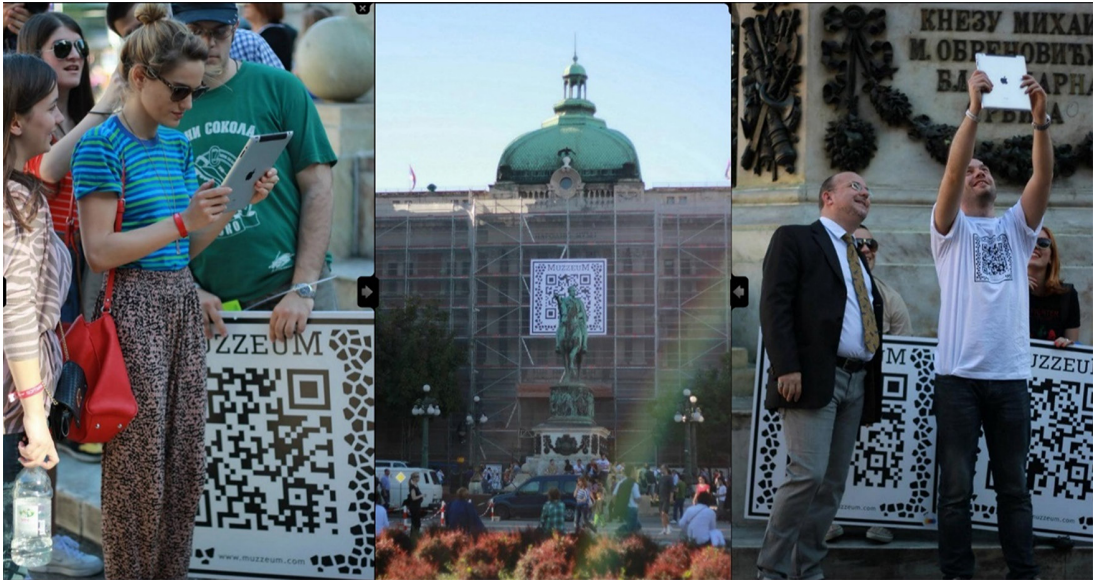
Figure 57. The Muzzeum Project, Belgrade 2012.

Augmented Reality can also be applied in the presentation of archaeological excavations. It is nowadays common that all archaeological field documentation is kept in digital form and the structures discovered are geo-referenced. It would thus be easy to show photos of artefacts at the moment of their discovery, provide ground plans of architectural features, show videos of excavations etc.

In order to acquire an insight into the current stage of application of archaeological reconstruction across the app market, I did searches using terms such as archaeology + field; + professional; + Virtual Reality and Augmented Reality. What I discovered was that there are not as many relevant applications as one would expect n this flourishing market.

At the time when I searched for archaeology + professional (August 2016), www.play. google.com suggested only a handful of apps. Of those, only three could be useful for professional work and these are: Precision GPS, Archaeology Sampler and Heritage Daily. My subsequent search included terms archaeology + field, and this one yielded not much more.

ARCHI Discover Archaeology claims that when using their app one can discover more than 200,000 British Archaeological, Historic and Cultural Sites in the database. According to them, they are the only online service available to the public that offers full details on the location of the sites in the database and the travel directions.

There are a number of archaeological guides (in print or available online) which can be used as a sort of tourist guides for this form of heritage and for Biblical archaeology.

At the end of the day, it seems that neither the technology, nor the method of data collection, nor the state of preservation of archaeological remains are as crucial for virtual reconstruction as is the interaction between the author of the reconstruction and 3D modellers, texture artists and programmers.

One should not forget the prospect of publishing in the interactive form, as exemplified by the excellent presentation of the Roman site of Torreparedones in Granada, Spain. In this interactive publication, downloadable from https://play.google.com, one can see an abridged version of the site's monograph, chapters and all, just like in a "real" printed book. The chapters are ordered in the way they would be in a monograph: the introduction is followed by a chapter on the landscape, then comes chapter on the history of research, followed by chapters on the individual investigated structures. In each of them, the elements used in the virtual reconstruction are provided. In addition to the gallery of photographs and drawings, which form part of the field documentation for the site, video-material is also offered, as well as 3D reconstructions and Augmented Reality, completing the well-rounded guidance of this interesting site. This example provides an overview of all of the currently available options offered by virtual reality technology. What is problematic, but certainly not a responsibility of the authors of this outstanding presentation, is that, according to the play.google.com record, the application was downloaded by only a little over a hundred people.

This kind of applications is rare on the application market. Unfortunately, in case of some other similar applications, the number of downloads also remains below 500. The reasons for this situation are diverse and can be found in:

- The present lack of interest of the culturally competent audience for IT achievements;
- Poor marketing of the products that mainly relied on funding from the local communities and/or ministries of culture, and thus did not require marketing for fundraising;
- The view that presentations of this kind are only useful if incorporated in the actual tourist offer of the respective cultural heritage monument;
- The absence of interest in the commercial sector for the products publicising cultural heritage.

A question arises as to which types of audience VR in fact targets? This is where the situation becomes highly complex. Namely, VR is not a product that can be created rapidly – quite the opposite. From the moment one decides to venture into this sort of enterprise, it takes years to realise the idea. The VR production process could be divided into two equally complicated and demanding stages: fundraising and creation of the reconstruction.

The new version of Android, released in the course of writing of this book, introduced Android Nougat and the accompanying split-screen display mode in which two applications can be snapped to occupy halves of the screen. An experimental multi-window mode is also available as a hidden feature, where multiple applications can appear simultaneously on the screen in overlapping windows. This will be particularly suitable for the VR content requiring the use of VR eye-glasses, and there will be more and more of this kind of content. This is a window of opportunity for archaeology.

Also, any VR demands high input of time and labour that is not cheap. One should not forget that, unlike archaeologists and art historians, IT engineers are very well-paid and do not lack job offers. It is thus essential to raise enough of funds to be able to hire good modellers, programmers, texture artists and others, in order for the VR to be sufficiently interesting to the spoilt and difficult-to-please audience in the habit of watching Hollywood mega-spectacles such as 'Captain America' or the mastodon series of the kind of 'Game of Thrones'.

Thus, young generations that, once they grow up, will represent the consumers of our VR creations, have already been used to 'surreal', to the products of imagination; there are not many of them that will have concerns about whether or not a cultural monument was reconstructed according to the latest scientific discoveries.

However, given the present state of circumstances, despite the exceptionally well designed and attractive offers there lacks a public interest, especially in the field of Classical Archaeology.

A sudden boom of smart mobile phones and tablets started in the last quartile of 2010 with the introduction of the Gingerbread version (Android 2.3) which, as a novelty, included the support for SIP VoIP internet telephony. Besides, this was also the time when the support for higher resolutions and faster screens was introduced, which was conducive to the development of 3D content, above all games. As a by-product of this advancement, the profile of the target audience changed.

The nature of the target groups is as follows: the ones growing up, so-called *millennials* or ditigal *natives*, who are surrounded by computers and screens and 3D models as part of the video games they play. They only pay attention to the models in the context of the event shown on the screen or, clearly, if the 3D model is of inadequate quality. This has set high standards to be achieved by 3D modellers and texture artists. Also, these generations do not understand virtual reconstructions if the action is missing, they see them only as the beginning of a game in which the characters do not turn up after all; thus, bored and contemptuous, they abandon them after only a few seconds, with the typical question-answer "So?".

In the summer of 2016 the PockemonGo game was released, amidst enormous interest worldwide, and it overnight attracted millions of users, cashing in an admirable amount of money already during the first week after the release. The profit-making trend continued and, in the following months, over ten million dollars were earned daily! It is anticipated that the sale of "pokecoins" will bring three billion dollars to the company Apple in the next year or two. The game essentially uses a GIS platform on which FIGURINES are placed. They represent characters from the eponym animated movie (Pokemon). What is of interest to us who are concerned with the cultural heritage and its preservation and promotion is the fact that, within the game, on the maps that the players observe and find their way around during the game, the shown landmarks quite often represent real cultural monuments.

The creators of the PokemonGo game have understood one thing that we, unfortunately have not — that the figurines appear alive and attractive only if in action. In the game they fight against each other, respond to the challenges placed by the player, they have personalities. Obviously, it is not wise to expect that academic projects will be overpowered by the challenge and start creating characters based on ancient heroes in bloody battles in order to secure decent 3D models of the cultural monuments. They will continue to rely on anyhow modest financial support that they obtain from either local council of the territory in which the cultural monument is located (as is the case with almost all VR products in the application markets), or the local ministry of culture and tourism, or will benefit from the enthusiasm of small groups of private companies. No matter how high, these funds are nowhere near as high as the budget available to

the various teams working on developing video games. In other words, the introduction of a more substantial interaction, in addition to the simple walk through the models, is still far from sight. What we can, at best, see in present-day 3D visual reconstructions is smoke coming out of houses and huts and, in case of video rendering, one can even see a person or two walking aimlessly around the stage. Even if done to perfection, these kinds of reconstruction of the past are to the young people boring and can occupy their attention for a maximum of eight minutes.

So what do we do about this? How to proceed with creating virtual reconstructions when even the most attractive of them do not get downloaded from Android market more than a thousand times? How to make millennials interested in the cultural heritage?

One possible direction that I recognize is incorporation of authentic elements of the reconstructed cultural heritage into the entertainment industry. Whether this will be in the form of video games with bloody encounters in an authentic setting of a medieval fortress, or a time-travel game in which the characters explore past landscapes, is not of prime importance. What is important is to find a way that will enable the production of 3D models derived from archaeological investigations and their subsequent use in the domain of lucrative video-games.

Another possible direction would be the introduction of 3D reconstructions in school curriculums, their inclusion in textbooks for history and other subjects, where they would undoubtedly enrich the teaching and learning process.

So, the right question in the end would not be whether Virtual Reconstructions are good for archaeology or not, but instead: how do we get the means to do it as a standard procedure not only for presentation but also for analytical purposes and field documentation. 3D models of multiple objects geo-referenced and integrated in the field are still expensive undertaking, but building one using photogrammetric procedures is not. It can be saved and used later when an opportunity emerges that the entire excavated field could be fit together as an authentic recording of archaeological research.

So, is there a solution to this problem?

QR codes and image recognition solutions appear to have a great potential for further practical use, such as linking audiences and virtual reconstructions, thus making virtual reconstructions much more marketable. They represent the fastest links between the world of print and the world of digital, and are easily shareable. So we already have within our reach an effective way to offer/push additional digital information, and offer it to the audience in the form of a palpable object. On the back of a beer mat, on a kitchen tissue, on a placemat in a restaurant, on the side of a tram, stuck to a lamp post or on the wall of a museum or shared on a social network website, why not?

Augmented student textbooks, readers, tourist guides or maps could be amazingly handy source for including links to the contents of lessons in audio, video and 3D mode, presenting them in a way which is understandable to a digital native. Even without the need for re-publishing! Image recognition of existing contents of textbooks and other

printed material can overcome this obstacle. As far as interactivity is concerned, flourishing social networking could feature in different subjects thought at schools and universities, which could, in effect, significantly widen the target group for all sorts of cultural content. Printed items listed above are still popular even in the Age of Digital. Will the end of printed publications eventually change this? Who knows, probably yes, but there are still some years ahead for us to promote the importance of virtual reconstructions in archaeology and cultural heritage, and meet our objective which is – to incorporate possibilities of IT in our everyday praxis.

In the end, it turns out that the most vicious threats to the well-being of priceless monuments throughout the World are coming not from the usual set of risks described by experts in charters and declarations, but from ideologically instrumentalized people who have, through their abominable mindless actions, destroyed numerous world heritage monuments such as Palmira, Nimrud, Niniveh, Hatra and many more. And for that reason, after the destruction of Palmyra in August 2015, the Institute for Digital Archaeology (IDA) in Oxford, announced plans to establish a digital record of all historical sites and artefacts threatened by the ISIL advance. In order to accomplish this goal, the IDA, in collaboration with UNESCO, will despatch 5,000 3D cameras to their partners in the Middle East. The cameras will be used to capture 3D scans of the local heritage. Unfortunately, it is a bit late for Palmira, but this indeed shows the importance of accurate 3D scanning and virtual reconstructions of cultural heritage.

2D AND 3D VISUAL PRODUCTS: FIRST STEPS TOWARDS VIRTUAL RECONSTRUCTION

Ján Zachar (Via Magna)

The main product of 3D digitisation is a 3D model. It can be presented in 2D space (when a 3D model is basically converted to a 2D raster using specific visualisation parameters of the 3D model) or in full 3D space. 3D space presentation of the model can be of virtual nature (3D animation, 3D SW viewer) or of tangible nature (3D print).

2D Visual products

2D visual products are a standard form, especially in the professional sphere, where printed or digitally distributed 2D information carrier still prevails as the main means of communication (printed or digitally distributed publications, articles, etc.). 3D digitisation, as already mentioned before, most often fulfils the role of a means to create 2D or 2.5D professional documentation (primarily the technical or graphical part). In the context of cultural heritage, this applies especially to the creation of graphical appendix of archaeological or historical architectural research documentation. In addition to such practical function, 2D reproduction of a 3D model can have special importance thanks to the software-conditioned highlighting of visual parameters of the respective 3D model which, in many cases, can add value from the perspective of dealing with specific professional issues.

Technical research documentation

3D digitisation is, in research documentation, especially useful for the creation of geo-referenced orthophoto plans of layouts of the structures, scaled orthophoto profiles and facades (of historical building), and scaled cross-sectional views, which are subject to vectorisation mainly in the CAD environment. In addition, the creation of DEM, which is then subject to specific visualisation algorithms, is frequently performed in the analysis of historical and archaeological potential of the landscape.

3D documentation is also very suitable for the creation of 2D graphic derivates, which significantly reduces the time spent in the field. However, the experience from case studies shows that this work procedure also has limiting factors and issues that need to be taken into account. The most serious problem is represented by digitisation shadows, which can, in many cases, lead to the omission of documenting important parts of architecture or archaeological sites. This is problem is often hard to solve. For instance, if a massive, floor-to-ceiling piece of furniture is in close contact with walls of the space scanned, then this can distort the width of wall partitions since the wall is covered and inaccessible for scanning. It is difficult to secure perfect accessibility to all spaces in building interiors. Small, confined spaces in which it is difficult to position the scanner for 3D scanning, or spaces with light conditions that do not allow a reasonable number and quality of images to be achieved, can often be documented only by using the classic method of taking measurements. The number of photographs that would have to be taken for IbM is huge in the case of small spaces with a complicated layout. 3D documentation would thus be ineffective relative to the data obtained (spaces with sanitary facilities, storage areas, anterooms, spaces under stairs and other internal areas). This inevitably leads to "white areas" in the models of elaborate buildings and complexes (Grúňová & Zachar 2015, 67-69).

Scanning of upper floors of architectural structures is also problematic. Digitisation shadows are formed not only in case of small architectonic details, but also along window sills and edges of window openings. In such cases, the terrestrial scanning needs to be complemented with the data collection performed by an UAV or done from a higher platform (e.g. scaffolding). This is, however, technically very demanding, particularly in the case of (dense) tree vegetation and terrain of a complex structure and elevation often surrounding architectural remains (castles). Therefore, in many cases, 3D digitisation needs to be completed with conventional geodetic methods (additional measurement of parts that can be accessed only with difficulty using Total Station or measuring tape). With regard to the total volume of data in the instances of complex historical architectonic structures, it is often the case that dense point clouds form the basis for vectorisation, instead of the textured 3D models (mesh), as point clouds are easier to manage from the perspective of hardware parameters. However, this can lead to visual overlap of several facade layers into a single surface, in case ortho-inputs for vectorisation of cross-sectional views are prepared, and this can be very confusing (Figure 58).

As the context implies, it is necessary for the documenter to experience the object/locality by doing their own research; this can prevent incorrect interpretations in vectorisation of the data. The person processing the data must be familiar with the building/locality and also, in vectorisation, it is required of the person to have knowledge of the structural aspects of architecture in general and historical architecture in particular, with

all its specifics. A lay person without experience and lacking adequate perception of space and knowledge of structures cannot distinguish important from unimportant and does not actually *see* the structure (Grúňová & Zachar 2015).

Figure 58. Example of unwanted transparency of the point cloud in the generation of a cross-sectional view.

Finally, yet importantly, it needs to be reiterated that the creation of 2D graphic documentation as a derivate of 3D digitisation significantly expedites work in the field, but subsequent processing of the data in office is very time-consuming. The focus of evaluation moves, in case of digital methods, 'from the field to the desk', which can be beneficial for the rescue investigation. Hardware demands (RAM, processor, graphic card) are implied by the nature of 3D documentation as such.

Shading filters

The application of shading filters is not a specific feature of 2D visualisation. In their basic form, shading filters form a standard equipment of the majority of 3D viewers and 3D modelling software. However, they acquire special meaning principally at the stage of conversion of a 3D model into a 2D raster, when they allow, according to the parameters of the filtration algorithm, to highlight certain elements of the model's surface. This helps mainly in the analysis of the documented object from a professional point of view, where it represents an added value with regard to visualisation. In addition to the standard native shading filters that are applied directly to a 3D model, such as basic

shading, ambient occlusion and volumetric obscurance, special shading algorithms used in GIS applications for 2.5D models can be also used: the sky view factor and topographic openness.

Basic shading

Any shading of the 3D mesh is determined by the existence of normal vectors which, in a mathematical sense, are the directions that are perpendicular to the surface of any given location (Nehab et al. 2005). Basically, the normals tell the software which side of the mesh is to be regarded as the inside, and which as the outside surface. This is of utmost importance for the distribution of lighting over a 3D model, as light bounces off surfaces in such a way that the angle of the incident light and the angle of the reflected light are equal to the angle of the surface normal. False normals' position can thus cause inadequate lighting and part of the internal side of the model can be wrongly visualised as the outer surface, or vice versa (Figure 59).
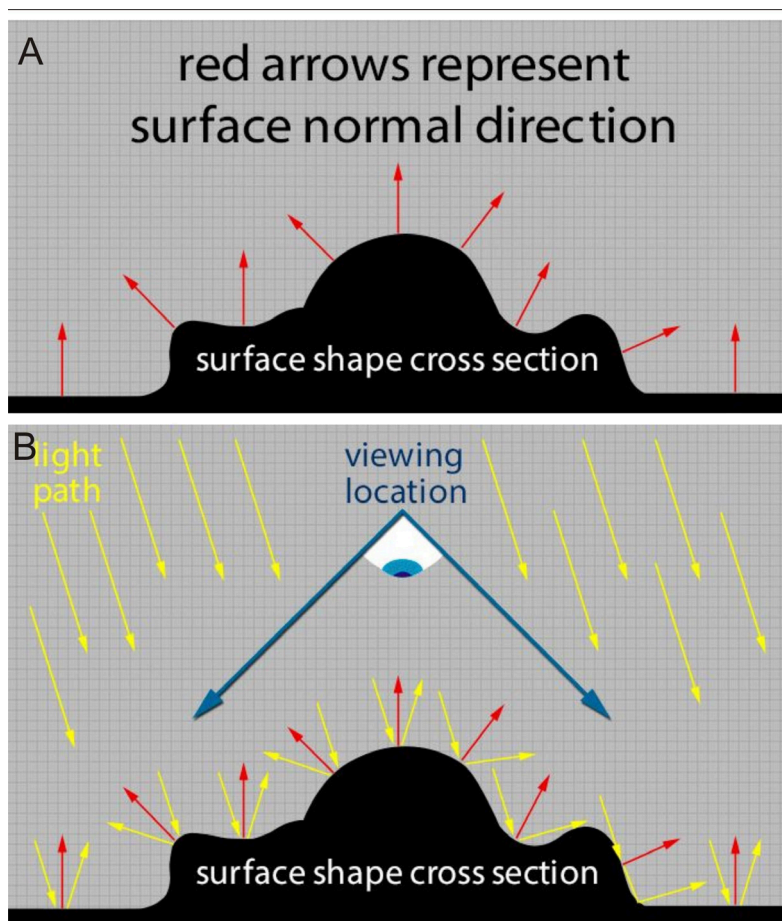
Figure 59. Demonstration of how normals function by shading a 3D model. A: position of normals' vectors in reference to the model's surface, B: visualisation of the light reflectance according to the position of normals. Available online at http://culturalheritageimaging.org/Technologies/RTI/.

Most IbM software generate normals when exporting a 3D model. On the other hand, TLS data (point clouds) contain information on normals only when saved in PTX file format. In other cases, normals have to be computed separately, either directly upon the point cloud or after the mesh generation.[1] Most modelling software, as well as 3D viewers, nowadays enable multi-directional lighting systems, which include several partly or fully manually adjustable lighting sources that create illumination of a 3D scene according to particular needs.

Radiance scaling

In the open-source MeshLab SW there are a lot of shading filters for improving or altering standard visualisation of a 3D model. The most useful amongst them is definitely *Radiance scaling.* This rendering technique is aimed at visualising shape by shading through the modification of light intensities around specific features. The main goal is to correlate shading with the variation of the surface features in order to enhance the shape's plasticity by visually augmenting concavities and convexities. The *Radiance scaling* rendering technique works in real-time in modern graphics hardware. As a consequence, surface features can be inspected interactively (Granier et al. 2015). In general, this shader augments the surface by changing reflected light intensities of the model based on the surface curvature and characteristics of the material. It is focused on emphasising surface concavities and convexities, which make plasticity of the surface geometry more obvious. In this sense, parts of the surface can be made more visible than they are under standard illumination.

The shader offers several display modes (Lambertian scaling, Colour descriptor, Grey descriptor and Lit sphere scaling), each containing an enhancement slider. Lambertian radiance scaling produces light grey visualization of the mesh, whereas carved areas are shown in a darker shade of grey. The grey descriptor also changes the visualization to grey, but uses darker colour tones. Colour display mode operates on the same principle as grey descriptor, but generates multicolour output scheme. Lit sphere scaling enables the transition of scaling dominance either for concavities or for convexities, thus changing the default balance between them. Unlike other display modes, the Lambertian can be joined with the basic shading lighting. This allows the user to highlight the model from different perspectives. Other modes use static light, so when the model is turned around, the edges of the surface remain visible. This makes it easier to get an overall perspective of the surface.

Ambient occlusion, Volumetric obscurance

Ambient occlusion is a method for computing lighting on the surface of an object that takes into account the light brightness due to occlusion of the surface in relation to the light source. In fact, it is a type of light in computer graphics that is used to simulate general illumination. In its essence, it is a way of simulating shadowing caused by objects blocking the ambient light. In general, visualisation is most often calculated by casting

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1   For this purpose, MeshLab or CloudCompare (both open-source) can be used.

virtual rays in all directions from the surface. The rays that reach the background or 'sky' increase the brightness of the surface, whereas a ray that hits another object does not contribute to illumination. As a result, the points (mesh triangles) surrounded by a large amount of geometry are rendered dark, whereas points (mesh triangles) with little geometry on the visible hemisphere appear light (Coombe 2015). In other words, parts of the model's surface that are 'open' are visualised in a bright way and parts of the surface that are 'occluded' are depicted in dark tones.

Besides the professional graphic and 3D modeling SWs, the easiest way to compute ambient occlusion rendering is to use open-source SW CloudCompare or MeshLab. In both cases, the illumination of a point cloud or vertices of a mesh is calculated as if the light is coming from a hypothetical hemisphere or sphere around the object. Several parameters are to be set in order to run the calculation. The most important parameter is the cone amplitude which determines the extent of the (hemi)sphere that sends the light towards the object. The next component of the algorithm is the number of light rays sampled on the (hemi)sphere and directed towards the model's surface, which influences the level of detail. The more rays used, the finer the results. The final resolution is based on the size definition of the depth texture (the rendering context resolution). From the point of view of the final output, *ambient occlusion* is very similar to *radiance scaling* as both shaders bring enhanced visual distinction of concavities and convexities of the model's surface, thus augmenting the plasticity of the model. Furthermore, *ambient occlusion* can produce slightly different visualisation forms when being deprived of the surface vector normals. In this case, the model acquires a kind of an 'X-ray appearance'.

A specific form of *ambient occlusion* is *volumetric obscurance.* The shader operates on the same principle, but avoids darkening of occluded parts of the model, which is very often the case in *ambient occlusion.*

Radiance scaling, ambient occlusion and volumetric obscurance are all suitable for pointing out particular features on the surface with few variations. They are especially useful for the detection of attributes and various visual patterns on flat geometry, where shapes and patterns are carved into the surface of built-in bas-reliefs (e.g. ancient tombstones, votive stones with inscriptions etc.) (Figures 61, 62). The detection of such features can also be achieved by the application of a special lighting system, or the so-called Reflectance Transformation Imagery,[2] but both of the procedures have quite a few special requirements that have to be met on the spot, which is not always manageable or requires special equipment. On the other hand, 3D modeling with the above-mentioned shading deliverables is easily done on the spot, with minimal endeavour, and mostly requiring only a camera.

Another possible field of application of shading algorithms is the recording of historical sculptures. Especially, draperies and facial expressions can be substantially underlined, thus enhancing the overall dynamic movement and plasticity (Figure 61). In this sense, IbM, in combination with shading algorithms such as *ambient occlusio*n and *volumetric obscurance*, can be used for a better visual understanding of tangible art.

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2   For Reflectance Transformation Imagery see: http://culturalheritageimaging.org/Technologies/RTI/.
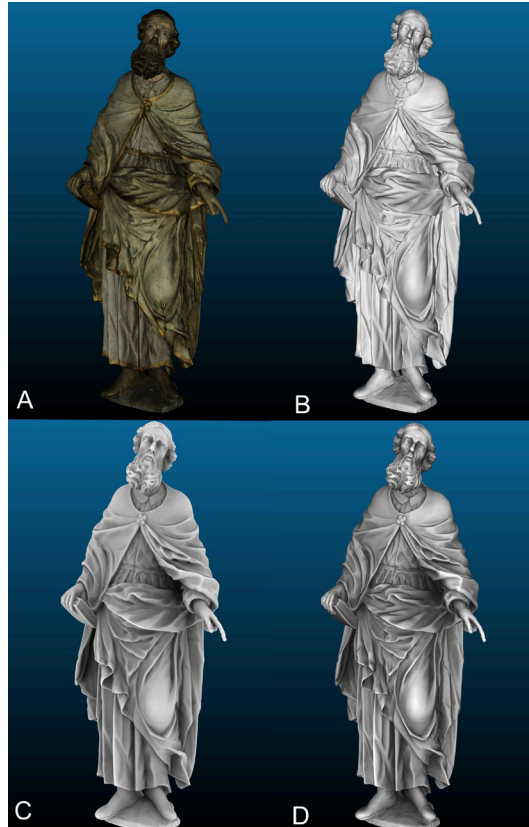
Figure 60. Various shading algorithms applied to a 3D model. A: textured 3D model, B: basic shading according to normals, C: ambient occlusion with normals off, D: ambient occlusion with normals on.
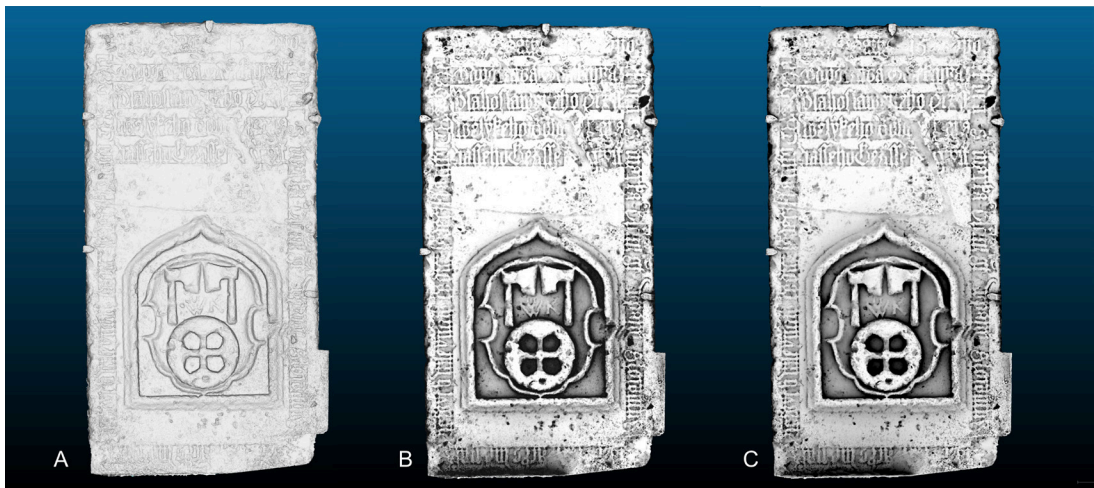
Figure 61. Ambient occlusion on the model of a 16th-century tombstone (bas-relief). Software Workspace CloudCompare. A: basic shading, B: ambient occlusion with normals on, C: ambient occlusion with normals off. Both ambient occlusion variants show very well the coat of arms and the writing on the tombstone.
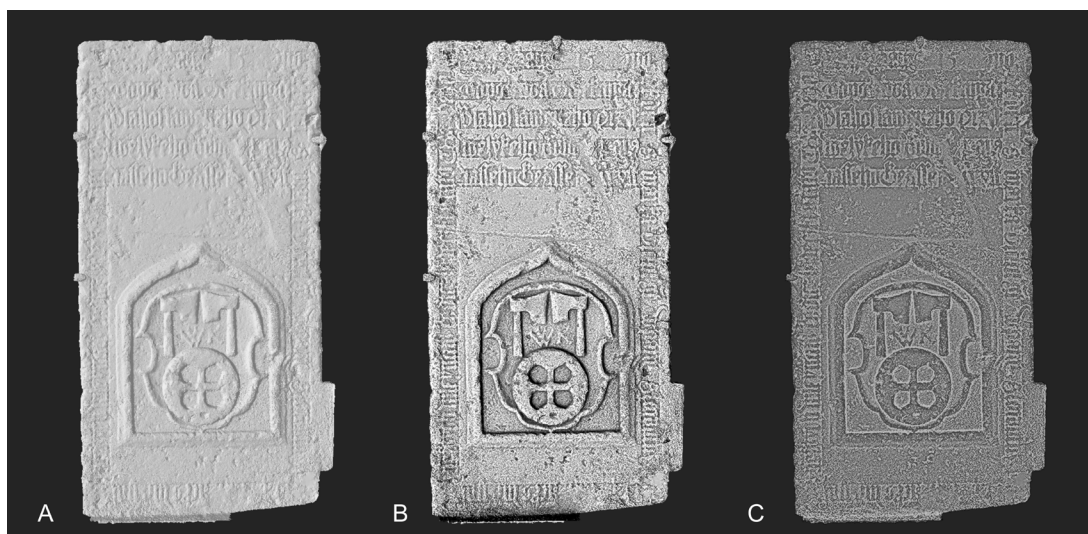
Figure 62. Examples of the usage of radiance scaling on the model of a 16th-century tombstone (bas-relief). SW Workspace MeshLab. A: basic shading, B: Lambertian radiance scaling, C: radiance scaling-grey descriptor. Both versions of radiance scaling enhance the appearance of the coat of arms and the writing on the tombstone.

3D Visual products

Until recently, 3D visualisation products have especially dominated the presentation sphere comprising mainly on-line 3D viewers (such as Sketchfab) and various types of 3D animations, saved in video files such as avi, mpg etc., most frequently allowing virtual flyovers over and around the 3D model. At present, 3D visual product offers a further benefit, connected specifically with the massive development of 3D print, which enables creating a more and more developed, tangible 3D copy of the digitised original. 3D print shows a huge potential, not only in view of the presentation and use in the popular sphere, but also in various professional sectors, such as the serial, standardised production of a prototype in the industrial sector, high-precision manufacture of medical prostheses and so on. In the field of cultural heritage, 3D print could, in the future, lead to a significantly cheaper production of copies of important art objects and the production of copies of different quality, according to the requirements of the client. The possibilities are numerous and the only limiting factor is the project budget.[3]

While 3D print as the tangible deliverable of 3D digitisation is on the increase, certain stagnation can be observed in the field of dissemination and general utilisation of 3D models in the virtual sphere. The possibilities for sharing and disseminating 3D files still face difficulties in the processing and management of large datasets and this constitutes a substantial problem for the majority of web applications. The original extent and size of

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3   There are nowadays many projects aimed at the creation of full-fledged replicas at 1:1 scale by means of 3D print of the digitised originals, e.g.: http://www.arctron.de/de/galerie/galerie_archiv/2016/feuchtmayer_statue/

the files are unmanageable for the majority of web viewers (currently, the most widely used Sketchfab cannot work with mesh of the size exceeding 10 million triangles). Similar problems apply also to the generally distributable off-line file type for depositing 3D models – 3D PDF. Similarly, many graphic SWs are significantly limited as to the size and resolution of the mesh with which they are able to work.[4] There is thus a considerable discrepancy between the potential of IbM SWs, which are currently able to generate 3D models of the size of up to several million of triangles, with extra high resolution showing very fine details on the one hand, and significantly limited capacity of their 'reading' by external modelling SWs on the other. To this end, the issue of general management and administration of the data, as well as the issue of effective retopologising of the original 3D data aimed at maximum possible reduction of the file size, whilst preserving all substantial details of the digitised object, remain important.

SW Platform	Web	License	Solution
Autodesk 360 Viewer	https://a360.autodesk.com/viewer/	open-source	on-line
Sketchfab	https://sketchfab.com/	open-source	on-line
3D Viewer online	https://www.3dvieweronline.com/	open-source	on-line
3D Viewer	http://3dviewer.net/	open-source	on-line
STL 3D Viewer (only STL files)	http://www.viewstl.com/Fig	open-source	on-line
Open 3D Model Viewer	http://www.open3mod.com//	open-source	desktop
ShareMy3D	https://sharemy3d.com/	open-source	on-line
3DReshaper Free Viewer	http://www.3dreshaper.com/en/software-en/download-software/free-viewer	open-source	desktop
MarmosetViewer	https://www.marmoset.co/viewer/	commercial	on-line
Geomagic Verify Viewer	http://www.rapidform.com/products/xov/explorer-free-viewer/	open-source	desktop

Table 1. Overview of the most commonly used 3D viewers.

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4   Usually, the upper limit of the resolution is around 30 million triangles.

SUMMARY AND CONCLUDING REMARKS

Nenad N. Tasić (University of Belgrade) & Predrag Novaković (University of Ljubljana)

The question as old as the conservation of cultural heritage itself is posed again: How much freedom are we allowed when reconstructing an artefact or a structure according to typologies and analogies. This question has been revived, but there is now an important new aspect to it – namely, in case of virtual reconstructions, the object itself is in no way changed or altered. The reconstruction based on the interpretation does not become physically real and involving interference with the original object or structure, but it is still one that is possible to present widely, and discuss on various levels.

A very interesting perspective has recently been offered by Piccoli (2014) in which she demonstrates her awareness that "3D reconstructions are problematic since they are the product of an interpretation process that entails the integration of heterogeneous sources such as historical texts, epigraphic material and geophysical survey to supplement the information that is missing from the archaeological record. This process results in formulating an educated guess on what the past looked like and it needs to be clearly documented in order to offer an intellectually transparent 3D model" (Piccoli 2014). Frischer et al. (2002) suggested that a "new philology" was needed for 3D archaeological visualizations, making an analogy with how philologists prepare a corrupted text for publication by providing an *apparatus criticus* to explain their integrations. Presenting the sources and the thinking process that leads to the choice of one reconstruction hypothesis over others is, in fact, the only way in which the research community can assess the scientific value and the reliability of 3D models.

This theoretical stand is valid and insists on creating 'intellectually transparent models'. Such an approach offers various possibilities to utilize 3D reconstructions and amassed 3D models of cultural heritage, but retain scientific methodology. Computer environment

is an ideal one for providing plethora of information which is available either from the literature, or from archaeological excavations and research, or from other disciplines whose knowledge is included in the reconstructions.

This volume presents, or rather, it is a result of a more eclectic perspective and does not follow one theoretical standpoint regarding the implementation of the VR products in archaeological interpretations and presentations. One of the reasons we would like to stress here are experiences of the authors who all had long careers in field archaeology and preventive research, and are still working in this branch of archaeology. It is these experiences which considerably influenced the ways how the VR reconstructions are considered and put into use. The perspective of being and working mostly on the professional side of the archaeology clearly reflects in the presented papers. In other words, the needs for consideration and implementation of VR reconstructions stems also from the need for improving the quality and relevance of the day-to-day archaeological practice and endeavours in the field and laboratories. In fact, it is this day-to-day practice which puts numerous archaeologists into situations where they have to constantly reflect their work and potential results and products.

As it was stated in the introductory chapter to this volume, the CONPRA publications are produced and aimed at younger professionals predominantly, but not exclusively, working in preventive archaeology. It is this population of archaeological experts who are working in increasingly competitive environment which requires constant capacity building for facing current challenges.

The introductory paper is followed by nine papers focusing on some major (definitely not all), aspects connecting archaeological practice and VR presentations and potentials. In doing this, we have attempted to cover some essential theoretical issues (Chapters: Introduction to virtual reconstructions; Physical vs. virtual reconstruction; Augmented reality as an output), technological aspects (Chapters: A comparison of different software solutions for 3D modeling), learning basics of visual products (Chapter: 2D and 3D visual products: First step towards virtual reconstructions) and a series of case studies and examples (Chapters: About digital field documentation; Brief overview of examples of VR projects; Virtual reconstruction of the Vinča-Belo Brdo site; Examples of good practice in 3D visualisation in preventive archaeology). It is important to note here, that with the exception of three cases presented in the chapter Brief overview of examples of VR projects (Catalhöyük, Uruk and Etruscanning 3D project) all other papers derived from the archaeological field research performed by the authors who had the possibility to control all different aspects involved in a complete research, from logistics, field execution to interpretation and presentation of the results. While this may not be so relevant for the VR products themselves it is highly relevant for demonstrating some other important aspects regarding professionalism in preventive archaeology, especially the learning capacities and 'organic' development and transfer of knowledge of new ideas and technologies. If preventive archaeology is to go beyond the level of basic field service and strengthen its relevance, which is constantly challenged by other stakeholders in spatial development process, it is necessary also to build up on the experiences and knowledge of the practitioners of preventive research. Here the transfer of knowledge is clearly multi-directional process in which VR can provide excellent communication or transfer tool, or language for communicating within archaeology, with other stakeholders involved in the archaeological research processes and practices, and public.

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