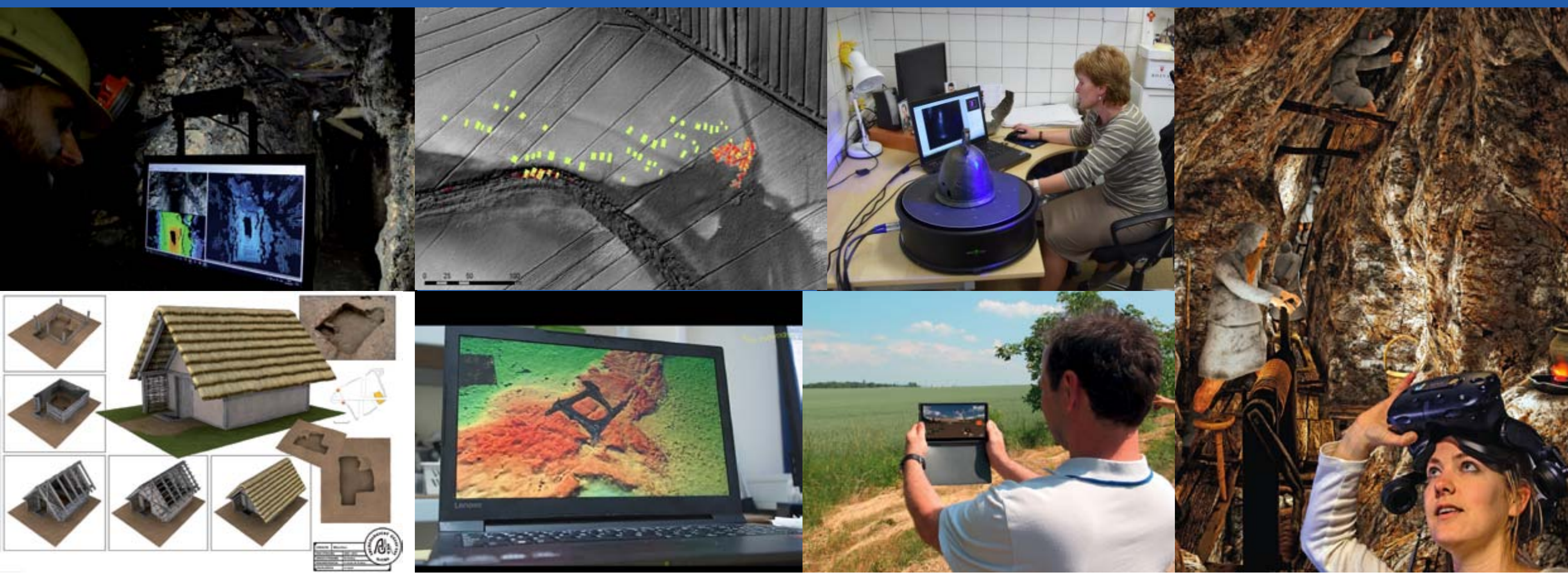
Interreg
CENTRAL EUROPE
European Union
European Regional Development Fund

VirtualArch

VIRTUAL ARCHAEOLOGY
MAKING THE INVISIBLE VISIBLE

Recommendations and strategies in the application of 3D digitisation and visualisation of archaeological heritage



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Chapter I

What is virtual archaeology?

"Virtual archaeology is a discipline that attempts to organize the vast archaeological heritage through computer-aided visualizations." (Victor Manuel López-Menchero Bendicho 2013)

Creating images belongs among the most complex human activities, and the image is by far the most powerful communication tool. If we look at an image, such activity does not involve just visual perception and the evocation of a particular emotional experience, but it also spontaneously leads to cognition. First, we see, then perceive, think, and make decisions. In fact, the most crucial part in the process of visual perception takes place only in the course of information processing. The visual perception does not, therefore, represent just stimulation of the ophthalmic receptor, but involves a whole range of processes because the optic nerve and retina are connected to the entire nervous system. The sight, out of all five senses, provides the brain with the vast majority of all sensory stimuli (fig. 1). Thus, the visualisation is actually a means of displaying and transmitting information in the most comprehensible graphic form. Compared to verbal or textual communication, visual communication is a much more effective form as it is faster and works in parallel and many dimensions.

Fig 1: The showcase "Caveman VR" (in the studio TRIAD Berlin) uses VR technologies to connect the virtual resting place with the real felt warm torch (TRIAD Berlin, https://www.triad.de/de/projekte/caveman-vr/).

As early as 1817, the English poet Samuel Taylor Coleridge postulated that the human imagination should be equipped with a momentary voluntary suspension of incredulity in order to surrender to an illusion for a moment, trusting what was written. Two hundred years later, museum visitors and Internet users also trust to enter a place of truth where they can put aside their scepticism and believe the descriptions and stories substantiated by material objects or research. Museums and trustworthy archaeological websites do not usually create fiction, but rather present scenarios based on scientific evidence so that visitors and users can view the objects and findings in a thematic context. Our current perceptual behaviour is increasingly changing with the development of new technologies. Especially among the younger generations - the digital natives - consciousness resources such as concentration and interest are increasingly influenced by this.

Archaeological institutions have to react accordingly and orient their mediation work towards these trends, also because the public now expects the visual and haptic provision of scientific results. Among other things, archaeological sources can be predominantly characterised by the fact that we can primarily observe only their formal, such as shape, material, colour, surface, decoration, dimensions, and spatial properties. Thus, archaeology is, in essence, a visual discipline, and pictorial expression shall remain one of the essential communication means for conveying information and its interpretation. However, the introduction of the latest digital technologies has provided the archaeological visualisations with a completely new dimension. As a result, the visualisations have become three-dimensional, multifunctional, virtual and interactive. Technological progress has influenced not only the ways of obtaining and processing data but also greatly expanded the possibilities of exploring them, especially the possibility of simulating various aspects in a virtual environment and visualising them.

For the understanding and communication of our cultural-historical development, narratives and scenarios of pre- and historical events involving people, objects and their surroundings are particularly suitable. These are most actively, and online ascertainable and experienceable by the instruments of virtual reconstruction artificially created reality (virtual reality: VR) and augmented reality (AR) applied in virtual archaeology. The term Mixed Reality (MR) is used to describe the gradations between the real and the virtual environment (fig. 2). In it, digital objects exist and interact with the physical, mostly visible environment through electronic screens of smartphones, tablets or smart glasses (VR glasses).

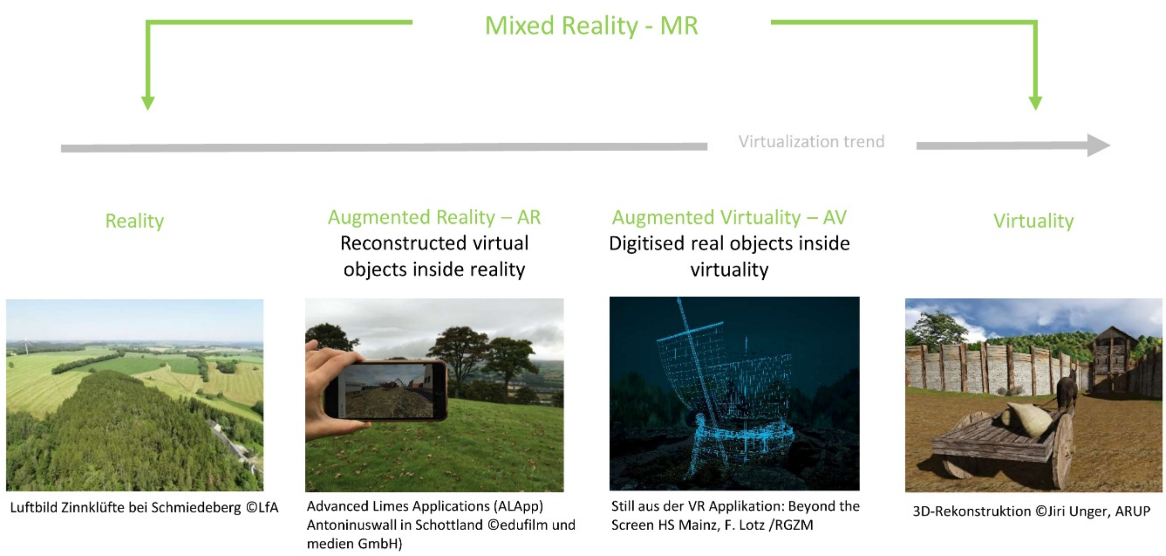

Fig. 2: The individual gradations of the Reality-Virtuality Continuum according to Milgram and Kishino (Aerial view of tin fissures near Schmiedeberg © LfA Saxony, Advanced Limes Applications (ALApp) Antoninus Wall in Scotland © edufilm und medien GmbH, Still VR Applikation: Beyond the Screen HS Mainz © F. Lotz /RGZM).

From the 1970s onwards, archaeologists, together with IT specialists, have developed numerous concepts such as Virtual Archaeology, Virtual Heritage, Virtual Museums, Digital Heritage, Digital Archaeology, Digital Cultural Heritage or Cyberarchaeology to make these technologies useful for the field of archaeology. In 1970, for example, the English archaeologist Leo Biek launched the digital 3D reconstruction, and his fellow countryman Paul Reilly first used the term “virtual archaeology” in 1991.

Since then, virtual archaeology has been experiencing rapid development and spread, driven by the GIS developments of the 1990s, and the digital revolution of the 2000s. From remote sensing, archaeology took over the contact-free data analysis of sites using cameras, scanners or radar systems, which were supplemented with methods of geophysics and radar (fig. 3). In the 2010s, interactive and immersive - i.e. immersion in a virtual situation - approaches were added. Today, fast and computationally powerful smartphones enable the virtual mediation of complex archaeological content in a very uncomplicated way.

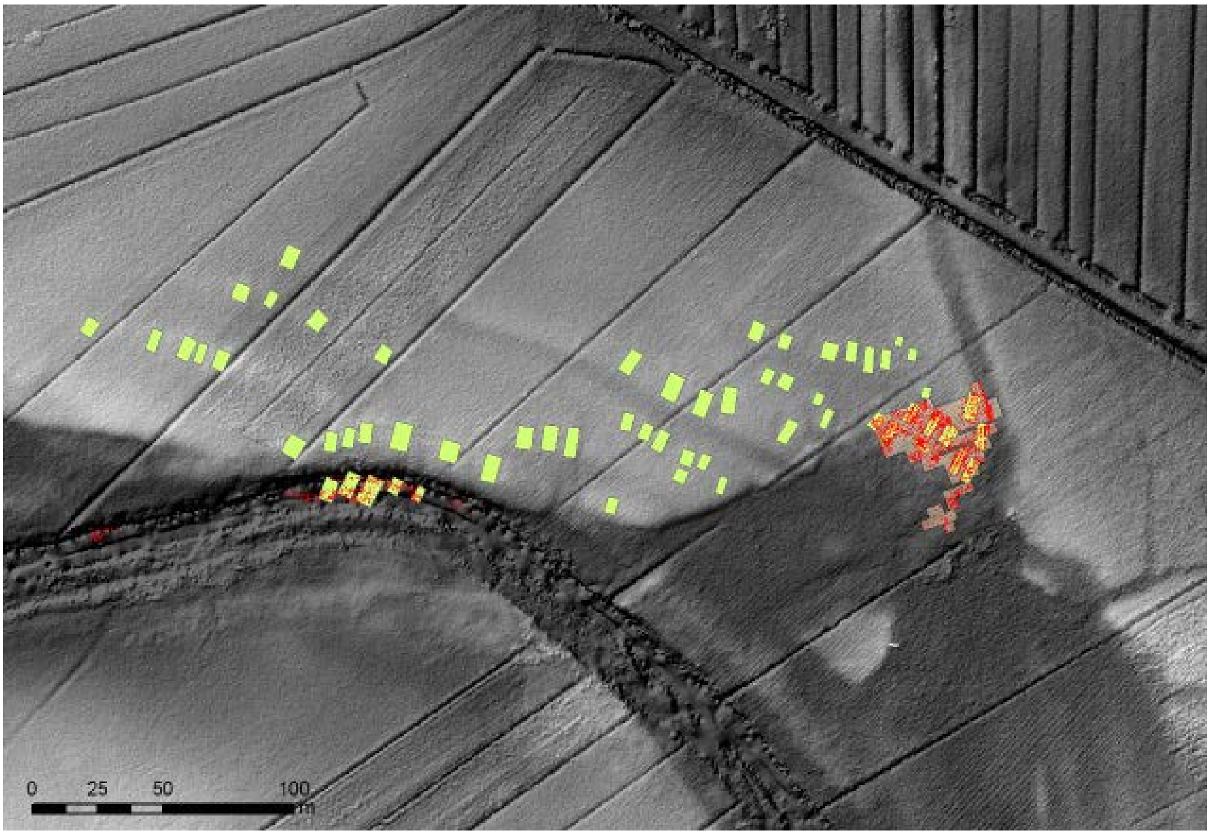

Fig 3: Hypothetical extension of the Maharski prekop pile-dwelling site in the Ljubljana marshes based on archaeological excavations, geophysical surveys, aerial photography and Airborne Laser Scanning (LiDAR) (image: D. Mlekuž Vrhovnik, Institute for the Protection of Cultural Heritage of Slovenia).

Why visualise archaeological heritage?

It is a rather challenging truth that the general public can only rarely really experience local archaeological monuments. Our archaeological and cultural heritage hidden in the ground usually only comes to light during archaeological excavations, for example, prior to building projects. The feature is then uncovered and documented layer by layer so that physically only the recovered finds such as ceramics, metal objects or bone and wooden tools remain. The public can then admire these objects - sometimes real treasures - in various archaeological museums. However, the finds are there removed far from the place of their origin (where they were found). There are only a few exceptional cases where display showcases are arranged to simulate the excavation site. Even archaeological monuments that are visible above the ground, such as burial mounds, castle walls or sunken features, mostly located in woods and protected from natural or anthropogenic destruction, are often difficult to access in the field. On such places, existing information boards are only partially accessible and comprehensible to the untrained eye (fig.

4). Other, partly very well preserved archaeological monuments such as the medieval mines in Dippoldiswalde in Saxony (Germany) are not accessible for safety reasons.

Moreover, a somewhat distressing fact about the presentation of the earliest human history is that its cognition largely remains ivory-towered within the closed professional academic and heritage management circles, and particular scientific projects. Therefore, there are almost no direct links between archaeological/historical sites on the one hand and the public or local people on the other, with, of course, a few exceptions. The effort to make the archaeological knowledge accessible virtually represents an alternative and desirable approach. By using virtual and augmented reality technologies, the archaeologists can quickly provide access to finds, features, as well as entire sites. The aim is to engage the public, which could lead to a better understanding of the values of the cultural and historical heritage, both on general, but also a particular level.

Fig 4: The public visible vs. "invisible" heritage – example of virtually reconstructed mining relicts in European forests (image: J. Unger, ARUP).

Archaeological monuments are rather particular due to their relatively high concentration and the fact that they are usually quite difficult to identify. Many owners have no idea that there are archaeological monuments on the land they own. Measures for their protection proposed by archaeologists or heritage management specialists are often in direct conflict with the current use of that particular land such as agriculture or forestry or with the construction plans and the demands of local governments.[1] Long-term and patient communication of all parties involved often results in the search for mutually acceptable compromises. For the general public, the key concept is to understand the nature of archaeological monuments and their vulnerability. The virtual and augmented reality is, therefore, the ideal tool for such type of communication.

While searching for instruments for effective protection of archaeological monuments, clear presentation of the archaeological heritage and communication with the general public have become a crucial topic in many European countries in the last few years. As part of this effort, the active involvement of the general public forms a focal point. Such a 'new' approach represents, to a considerable extent, reaction of a highly professionalised discipline that more-or-less alienated itself from the general public during the second half of the 20th century, whereby its promotional activities primarily relied on a passive consumer of the research results presented.

The effort to involve the general public in the systematic care of cultural heritage (fig. 5) also reflects in international conventions, namely the Convention on the Value of Cultural Heritage for Society, adopted by the Council of Europe in 2005 in Faro, Portugal. The document brings together *public authorities, professionals, owners, investors, businesses, NGOs, and the civil society* as a whole, and holds them jointly

[1] As a typical example, the demands of local governments to create enough underground parking spaces in the historic city centers exactly in places where there is usually evidence of the earliest local settlement.

responsible for the care of cultural heritage. If we compare the number of professional archaeologists[2] and the number of archaeological monuments, it is clear that only informed and educated general public can act as one of the main tools for sustaining the archaeological heritage protection.

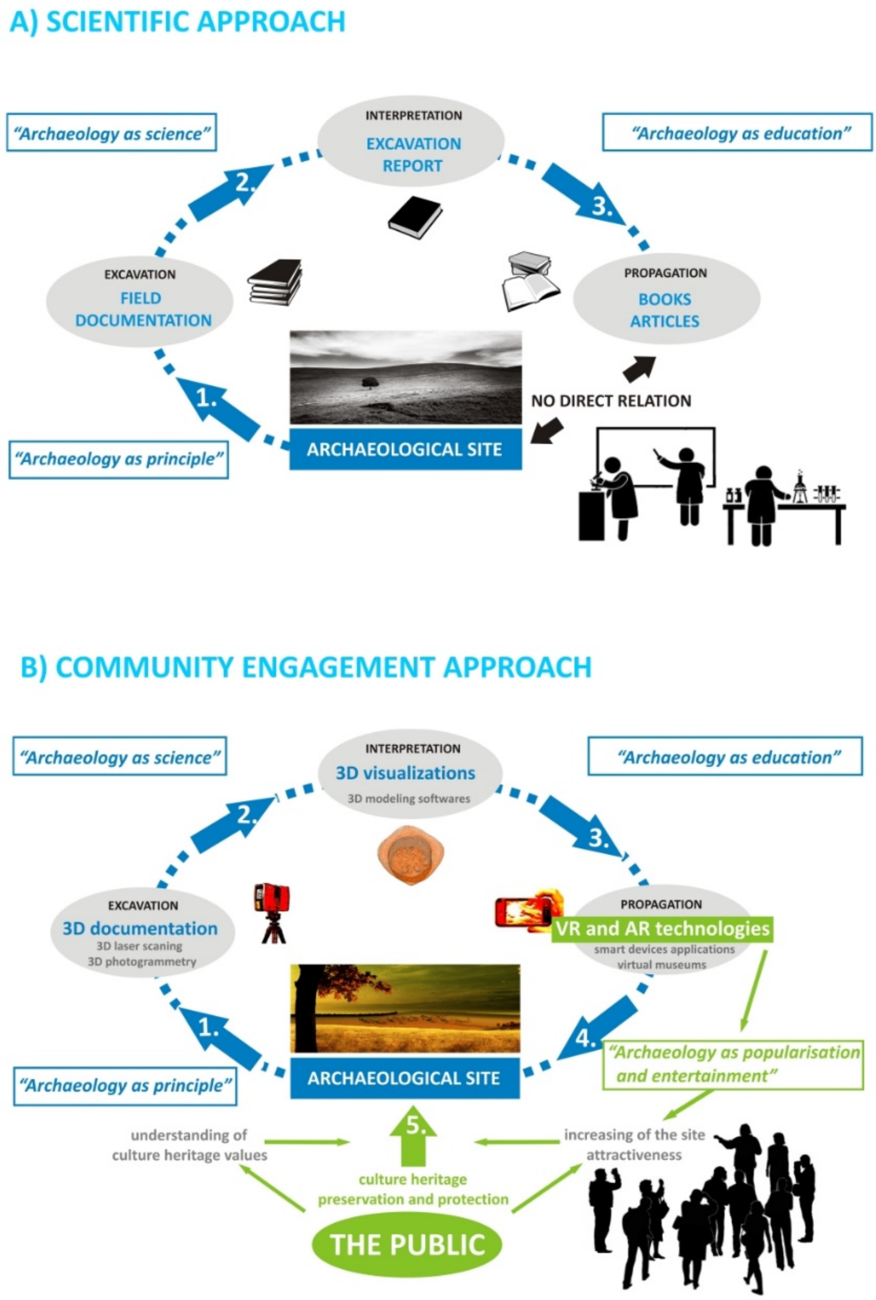

Fig 5: By extending the standard presentation mechanisms of archeology to include virtual space, it is possible to increase public awareness of the importance of archaeological monument care (image: J. Unger, ARUP).

[2] According to the results of the Discovering the Archaeologists of Europe 2014 survey, the numbers of archaeologists in most European countries range between 0.002% - 0.015% of the entire population, cf. Discovering the Archaeologists of Europe 2012-14: Transnational Report14: https://www.academia.edu/11686091/DISCO._Discovering_the_Archaeologists_of_Europe

Why use augmented and virtual reality tools?

The very rapid development of information technologies has created space for a change in the system and methods of presentation of archaeological features. By broadening the traditional presentation possibilities with virtual space, we have gained completely new presentation options. This is one of the reasons why terms such as virtual or augmented reality no longer represent mere science fiction concepts that are millions of light-years away but create a potent tool for archaeological conservation and popularisation. Virtual reality is a technology that allows its user to interact with a three-dimensional computer-generated environment displaying either real or imaginary space. On the other hand, augmented reality is a technology that enables to enhance the real image of the world by computer-generated virtual digital elements .

Mobile applications (fig. 6) represent a new possibility of displaying archaeological data in the virtual reality environment, in addition to the usual approaches using virtual museums on Internet, various touch screen applications in traditional museums or the phenomenon of PC games. The current mass expansion of smartphones opens up utterly new presentation options. While the traditional PC-based formats rely on the user's indoor perspective, mobile devices enable their outdoor use, e. g. they can be used directly on archaeological sites. The applications enable a combination of elements of the real and virtual world, which complement each other on the device display. The phenomenon of mobile applications, which combine the principles of virtual and augmented reality in order to present archaeological contexts, open up various possibilities to address the wide range of public and especially the computer-literate young generation who has already accepted the virtual space as a part of the existence. Such an approach can benefit from the already built infrastructure, i. e. the use of smartphones, which have stronger computing potential than the machines that sent the first person to the Moon. Their outputs are also easier to disseminate using native platforms for downloading applications of individual operating systems.

It is very likely that the form of virtual presentations of archaeological features and sites described above present a distinct trend for the future. Such an approach guarantees many benefits, including smooth and fast dissemination of information, as there is already an established and functioning infrastructure, namely a massive extension of smartphones and affordable Internet connection. Thus, such possibilities open the way to address the computer literate young generation who already perceive virtual space as a natural part of their real world. Building virtual presentations is much more comfortable, as far as organisation and financial demands are concerned, than the physical presentations. Moreover, the costs of operation and maintenance of mobile applications are essentially zero. Virtual open-air museums can also be created in an environment where other forms of presentation cannot be envisaged, such as directly at the site of a protected cultural monument or in a city centre.

Besides, the rapid development of information technologies has been significantly facilitated by the widespread use of virtual and augmented reality for the presentation of archaeological sites without substantial financial costs as there is a wide range of free tools. If 3D-data from reconstruction models or digital non-contact documentation is available, it can be presented free of charge in augmented reality by using the Sketchfab platform. After you install the application on your phone, it allows you to present and view all the 3D models that are loaded on the platform. Similarly, it is possible to directly present 360° panoramic images generated from a 3D model using mobile applications such as VR Media Player.

Fig. 6: The rising importance of mobile applications in the virtual archaeology (photo: Ch. Lobinger, Archaeological Heritage Office of Saxony).

An open platform for creating mobile applications that can be used for the presentation of archaeological sites was created within the scope of the VirtualArch project. We focused primarily on the user-friendliness of the application so that even complete computer novices can create mobile applications. All information and content can be imported via a website interface, and the user can upload texts, accompanying images, 3D models, and 360° panoramic images directly to the application and display them. Thus, users can interactively view 3D models, as well as 360° panoramic outputs from computer reconstruction models, just by swiping their fingers across the screen. The application also includes a map with points of interest and the current position of the user. The platform, thus, enables to create mobile application essentially as a website, which can be, consecutively, easily exported as a native application for all types of operating systems for mobile applications such as Android, iOS, Windows, etc.

The rapid development of technologies described above allows even small institutions such as museums to benefit from virtual and augmented reality presentation frameworks. Such institutions often stay outside large and well-funded projects dealing with this topic. However, as outlined above in the text, there are complete platforms increasingly expanding, which are either completely free or involve only a small investment in technological equipment. Considering the current trends in the creative industries, it is evident that the general public will, in the foreseeable future, exert increasing pressure to make these approaches to the presentation of archaeology a full standard. Individuals, as well as organisations, active in the care of our cultural and historical heritage should, therefore, pay particular attention to various aspects of the rapid development of virtual and augmented reality platforms used for the presentation and raising awareness of archaeology.

The EU-project VirtualArch – Visualize to Valorize

VirtualArch project focuses on the practical application of the innovative and trendsetting visualisation. One of the aims is to unveil regional archaeological heritage located underground or submerged, and partly with global importance (UNESCO), to local and regional stakeholders that are responsible for economic development.

Different to many other VR/AR visualisation projects in archaeology, VirtualArch approached through transnational cooperation with diverse heritage. Facing similar challenges and sharing the same objectives, ten partners from eight countries got together in three years running Interreg Central Europe-project, funded by the European Regional Development (project shall end in June 2020). The partner consortium comprises regional and national archaeological institutes and heritage offices, two universities/research institutions, and also two local communities as the heritage owners. On eight selected pilot sites all over Central Europe, their experiences were shared, distinct innovative visualisation and communication approaches were discussed and introduced, and unique applications tailored to the demands of each heritage site, and their audience developed.

Fig. 7: Pilot sites and partners of Interreg Central Europe project “VirtualArch – Visualize to Valorize” (© Archaeological Heritage Office of Saxony).

Such an eclectic approach is also reflected in the diversity of the pilot heritage sites, cf. fig. 7. The sites are characterised by various archaeological cultures, areas, environments, impacts and challenges. All of the sites contain unique finds, often from organic material (fig. 8), which allows vast insights into the past life and procedures and, thus, into international importance for research and the general public. However, none of them is accessible or even visible. Because of their complex structures, they are also hardly tangible, especially, for non-professionals.

Fig. 8: Wooden parts of a winch in a medieval mine under the current town of Dippoldiswalde (© Archaeological Heritage Office of Saxony; photo by M. Jehnichen).

According to their nature, the pilot heritage sites can be divided into four groups: urban area, landscapes, mines and underwater sites. Each of these groups has its specifics regarding, for example, the way of the gathering primary data, but also how they are presented to the public. Also, each pilot site has its specifications concerning the main goal its managers want to achieve.

Within the group of mining heritage sites, there are the prehistoric salt mines of Hallstatt (Austria), since l997 part of the UNESCO cultural landscape "Hallstatt-Dachstein/Salzkammergut" (https://dachstein.salzkammergut.at/en/world-heritage-hallstatt-dachstein-salzkammergut.html). Known in the scientific community for its famous cemetery excavated in the 19th century, Hallstatt belongs among the most important sites in European archaeology, thanks to outstanding results of excavations and experimental research projects that have been conducted by the Natural History Museum Vienna since the 1960s in the still active salt mines. Nowadays, the Salt Valley is already a popular tourist destination with an excellent infrastructure. Therefore, the project aims there at creating more precise and attractive ways of presenting the finds or showing them to the public a new light. On the other hand, the heritage is threatened seriously by natural movements of the rock itself.

Another important mining heritage site is located in Saxony (Germany) where unique and almost complete mines of the Middle Ages were found under the Town of Dippoldiswalde. As part of the "Erzgebirge/Krušnohoří mining region" (Ore Mountain), the Dippoldiswalde medieval silver mines were recently included within the UNESCO World Heritage list (https://www.montanregion-erzgebirge.de/en.html). The Archaeological Heritage Office of Saxony has been recording and recovering this outstanding heritage site since 2008. However, the site itself is – due to security reasons – not accessible and visible for non-professionals or tourists.

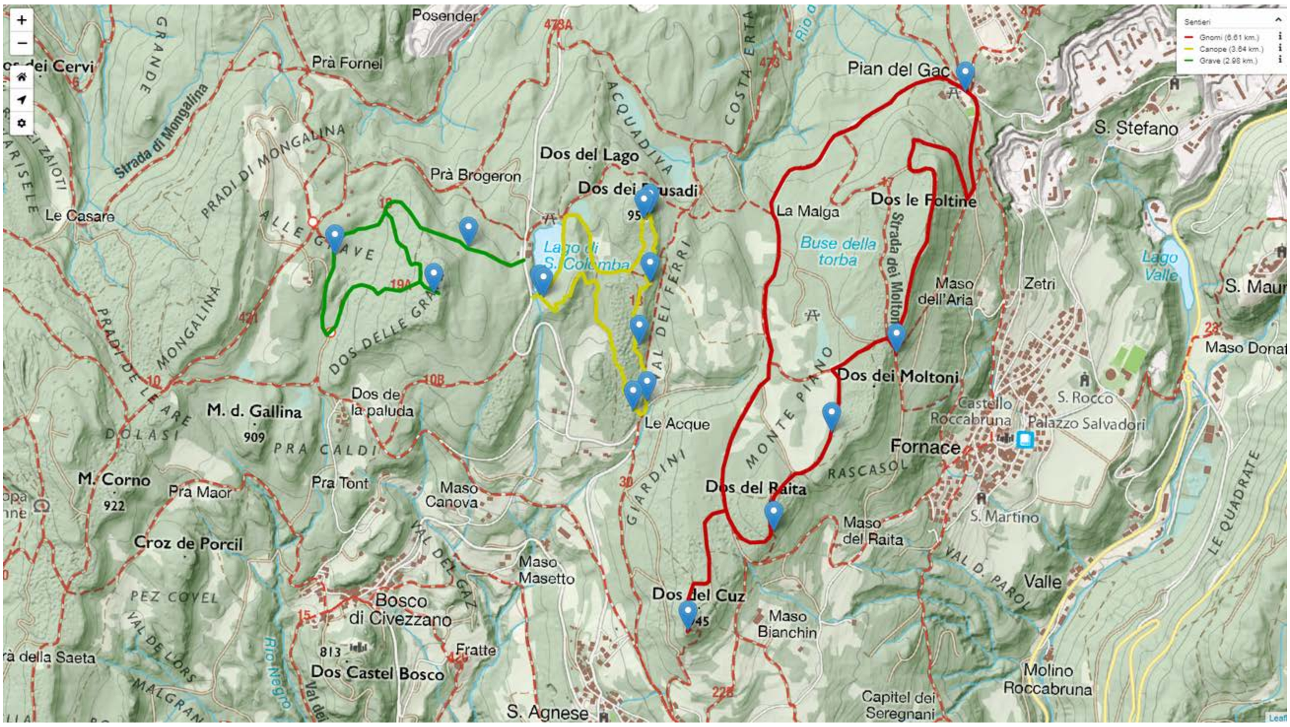

Fig. 9: Points of Interest in the mining landscape on Monte Calisio near Trento (© Autonomous Province of Trento.

Another vast mining landscape is located in the mountainous area around Civezzano (Italy), near Trento (fig. 9). Silver ore was exploited there extensively, especially from the 12th to the 15th century. So far, archaeologists have discovered a mining area full of sinkholes and gallery entrances covering over 12 sq. km. Due to security reasons, they are not accessible and threatened by agriculture and forestry.

A rather extensive and important mining and metallurgic settlement dating to the 13th and 14th century, together with visible mining relicts, was identified near Utín in the Bohemian-Moravian Highlands. The settlement, mostly known due to geophysical surveys, includes interesting features such as miners' houses, ore mill, a stamping mill or furnaces as well as a hospice and a filial chapel. The area is nowadays rarely inhabited, but agriculture and especially forest activities could endanger this interesting site. Identifying the full extent of the settlement, virtual reconstructions and target group-oriented lectures and tools may facilitate better understanding and, consequently, protection of the site, for example, by creating special exclusion zones.

Fig. 10: The castle hill of Nitra, Slovakia and example illustrating the complex archaeological stratigraphy (© IA SAS).

Urban archaeology is represented by the pilot site of Nitra (Slovakia), which was a princely residence since the 9th century. It also is of national importance as the oldest centre of early Slovak Christianity. The urban area of Nitra has been inhabited since the Neolithic period (fig. 10). Settlement layers and remains of rebuilding activities have made the archaeological sites there invisible to the visitors' eyes. The project focuses there on the visual presentation of the site that has been excavated for the last 30 years by the Slovac Academy of Sciences, as well as on small finds so that the public can appreciate the importance of the site starting from the smallest details such as a tiny cup up to the big picture.

In contrast to the latter example, the Slovenian pilot region is a large wetland area near Ljubljana. The extensive wetland area containing several prehistoric sites with pile dwellings has been enlisted on the UNESCO World Heritage list since 2011. The pile dwellings are a tremendous source of information not only for archaeology but also for dendrochronology, botanic studies, climatology, geology, and other fields of interest. The preservation of such an archaeological heritage site of global importance is, however, really challenging task. Ljubljansko barje constitutes a very attractive area that is densely used for agricultural. It is, therefore, highly endangered by the interventions of the local farmers, such as building new, deep drainage channels and the application of deep ploughing. Interactive landscape history visualisations and AR-applications, showing the currently invisible settlement structures should sensitise the stakeholders for better protection.

Fig. 11: Underwater survey at the Roman harbour Barbir near Sukosan, Croatia (© International Centre for Underwater Archaeology in Zadar).

Finally, the very specialised field of underwater archaeology is represented in the project by two important harbours. The first example is the ancient Roman harbour Barbir in Sukosan, located at the Croatian Adriatic Sea coast. There are several submerged stone structures (fig. 11), probably remains of piers or breakwaters, as well as pottery and small finds dating from the 3rd to 4th century. Although the International Centre for Underwater Archaeology has its seat in Zadar, only a few research and survey projects have been conducted there, and the site is almost unknown to the public. The second example can be found on the Baltic Sea, offshore of the Polish town of Puck. It is an extensive site that was used from the 10th to the 14th centuries. Over an area of 12 acres, several remains of the harbour construction, four shipwrecks, potsherds and bones dating from the 10th to the 14th century have been found there. Puck was probably the largest Early Medieval port in the southern Baltic coast, more significant than the well-known places such as Haithabu, Schleswig or Lübeck.

Although there are some differences between the heritage sites, the activities in the pilot regions are based on the same multi-stepped strategy:

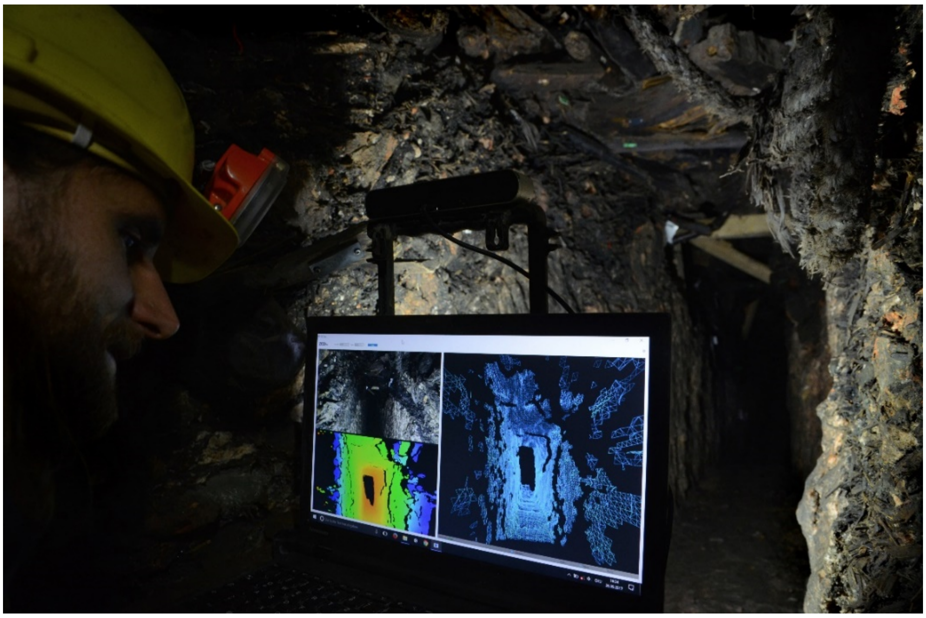

Fig. 12: Survey and digitization of prehistoric mines in Hallstatt (© Natural History Museum, Vienna).

First, all partners gathered and digitised data obtained from the archaeological pilot heritage sites shown on Fig. 12, including field surveys and aerial reconnaissance. Finds and archaeological features were 3D recorded by using different techniques ranging from structured-light scanners to photogrammetry and 3D scanning of finds, as well as hydroacoustic survey methods for the underwater sites. Obtained and processed data provided the base for modelling of the virtual reconstructions - the second step. Depending on the visualisation options and the "storytelling" behind it, the high-resolution meshes have to be reduced, missing items added or situations and textures exchanged, cf. Fig. 13. In the third step, the result – the almost realistic virtual model of a heritage site – will be visualised and presented by using various VR/AR options (see Chapter III).

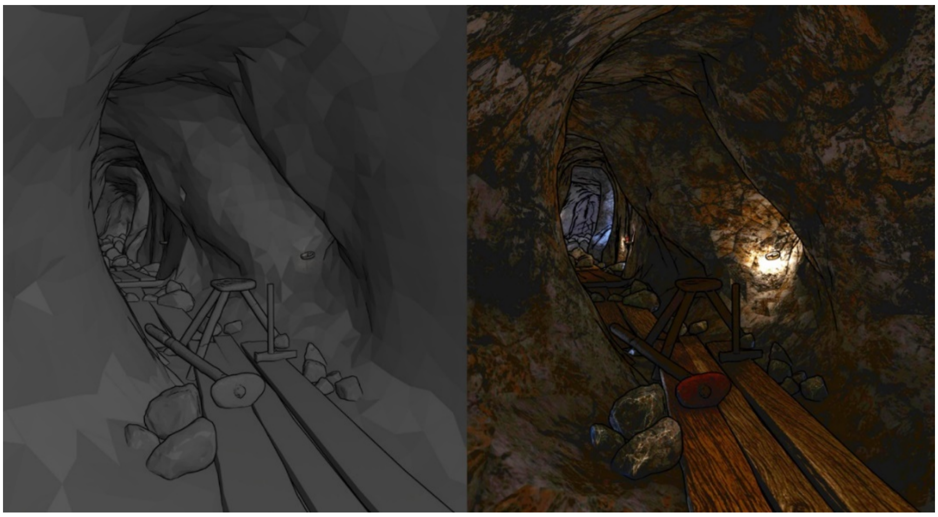

Fig. 13: Virtual reconstruction of a medieval mine based on archaeological surveys and digital documentation methods (©Archaeological Heritage Office of Saxony; image by J. Unger).

Virtual archaeology and its techniques as a remarkable tool for heritage communication and museums

"Showing 3D graphics on the screen is like looking into the sea through the glass bottom of a ship. Through a flat window, we observe an environment full of life; we consciously experience the fact that we are on a ship. Looking into the virtual world with a stereographic screen is like snorkelling. We are on the edge of a three-dimensional environment, looking at a depth of the ocean from its edge; we consciously experience the fact that we are sometimes in between, on the surface of the sea. Using a stereoscopic HDM is like putting on a diving suit and plunging into the sea. We dive into the environment, move around the reefs, listen to whale songs, collect shells and explore them, communicate with other divers, and understand the extent of the underwater world. We are there."

Meredith Bricken

The value of virtual archaeology or its approach using smart visualisation tools such as Virtual or Augmented Reality mirror especially in the form of various communication events the VirtualArch project partners participated in numerous times and presented there their visualisations (fig. 14). Just to name several such occasions: guided field trips at archaeological heritage sites, presentations and exhibitions on public, as well as scientific, conferences, museum and public events etc. Moreover, the audience has covered a wide range of social backgrounds, ranging from locals and foreigners over (business) stakeholders to politicians and significant decision-makers. All of them have one in common: their lack of knowledge about the hidden archaeological heritage "under their feet", its dimensions but also "the life in the past". Representations using different persons such as prehistoric or medieval miners or villagers make it possible to visualise details such as the distribution of gender, age and work in the past societies, costume reconstructions, use of tools, nutrition etc. All can be done simply and quite comprehensibly. Visualisations utilising coherent, lively overall pictures make it easier for the viewer to perceive and process the information in its entirety (fig. 15). The visual, three-dimensional and very life-like interactive impression promotes interest and understanding much more intensively than films, pictures, and lectures.

Fig. 14: Experiencing Virtual Reality on political celebration event in the German Embassy in Prague (photo: Ch. Lobinger, Archaeological Heritage Office of Saxony).

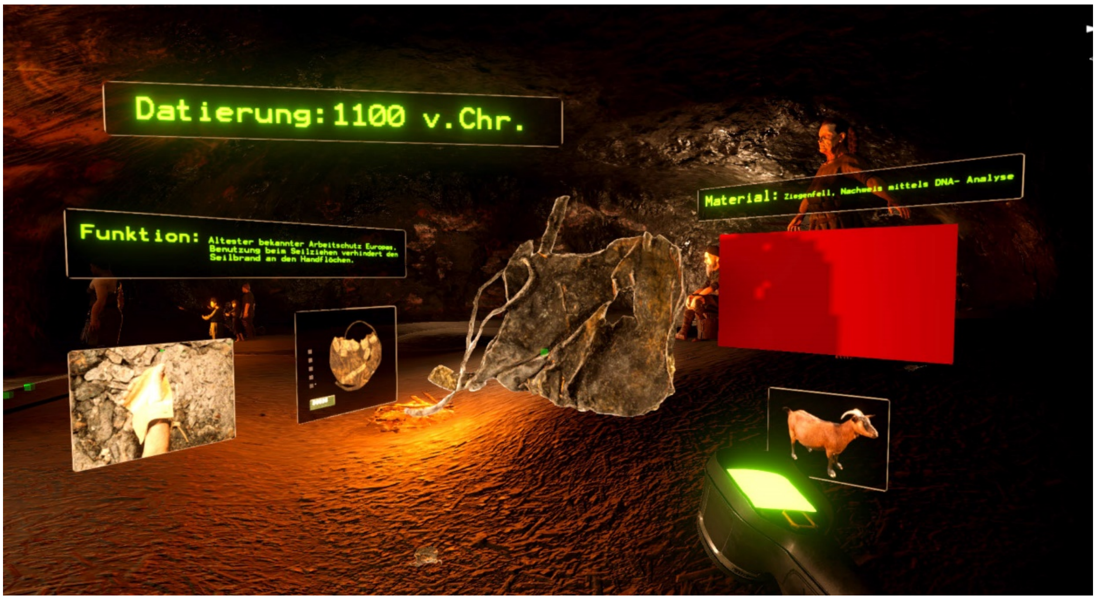

Fig. 15: Exploring prehistoric objects as 3D visualisation and their background information in its entirety - here a leather hand protection from the Bronze Age mines in Hallstatt (©Natural History Museum, Vienna).

People grasp considerably more details, approach real reconstructions more naturally in order to try them out and ask more in-depth and precise questions of the mediators. In all appearances, virtual archaeological tools leave a much more personal and lasting impression than all the previous impartion methods. Such experience can be even more enhanced by the recorded spatial sound of working noises, for example, in a prehistoric or medieval mine. People with almost no or weak interests in the “old stuff will be much more attracted than when standard communication lines are used. It is called the “wow-factor”, and it can be used to raise awareness.

However, the “non-professionals” are not the only audience group. Archaeologists themselves or other professionals dealing with the “hidden” archaeological sources for years (e.g. workshop of ALApp, fig. 16) are often amazed similarly. They are impressed, sometimes even proud of the circumstances that their “profession” or “heritage” could be visualised and connected to so many different sources visible. The playful, almost childish, approach to complicated and hardly tangible matters can play its role.

Fig. 16: Archaeologists and stakeholders of World Heritage “Frontiers of the Roman Empire” using the innovative ALApp (Advanced Limes Applications) on a field trip to Eining in Bavaria (photo: Y. Reichel/State Centre for the Non-State Museums in Bavaria).

Regarding the keyword playful, there is another concept or a means of communication that should be mentioned here besides the VR and AR, namely the games. Based on the same virtual models, it is, in fact, quite easy to create adventurous games such as Go Roman (https://play.google.com/store/apps/details?id=com.dds.barhillgame&hl=en) or the output of the Creative Europe project ALApp or Buchberg 1269 that was developed within the framework of the VirtualArch-project. Users step into a character, explore their virtual environment (such as a Roman frontier fort or a medieval mining settlement), fulfil various tasks, and learn about features and finds from archaeological evidence.

In the mobile application Buchberg 1269, the user has the opportunity to get acquainted with the site (its appearance and function), mining galleries and the adjacent processing district directly on the site through the created 3D reconstruction model of the medieval silver ore mining area at Buchberg (dating to the 13th and 14th centuries). In order to gain deeper involvement of the public, a game with a detective plot called "Devil´s Adit" was added to the application. The story takes place directly on the medieval Buchberg in 1269. The player assumes the role of a young knight Jacob von Zaun and gradually reveals the terrible plot that threatens the life of miners. On his way, he meets several historical figures who are directly connected with the site (based on the testimony of historical written sources) and visits particular places in the mines, which are in some way connected to the mining and processing of silver ore. The entire plot is resolved in underground galleries of the mine; the player has the opportunity to enter the galleries by using Augmented Reality.[3] The game platform, which has the potential to draw the site visitor into the story quickly, allows to provide not only computer reconstruction visualisation of the past mining area, but also naturally pass on information about the miners' lives and describe the entire medieval silver mining process quite entertainingly and originally. This type of action-based access to knowledge through direct interaction with the visitor can, thus, represent a desirable alternative approach how to quickly break down the barrier between the public and archaeology as a science.

Fig. 17: Fig. 4: Exploring Ancient Egypt – the "Discovery Tours" created by Ubisoft.

[3] The application for the Android OS can be downloaded here: https://play.google.com/store/apps/details?id=cz.mathesio.buchberg

The popularity of “experience the accurate past” events also reflects in the success of commercial PC games such as “Kingdom Come: Deliverance” (Warhorse Studios) or the game-series “Assassins Creed” (Ubisoft). The game “Kingdom Come: Deliverance” relies on historical events and an almost accurate reconstructed “world”, weapons and clothing; the action role-playing video game has gained several awards and more than 2 million sells. The series “Assassins Creed” is primarily known for its graphic details and stunningly accurate environment of the cities in the past. Currently, it has created an extended product line for impartion called “Discovery Tours” (fig. 17). It displays interactive worlds in great detail, for example, ancient Greece or Egypt; the player can discover there former living environments and everyday life of ancient people.

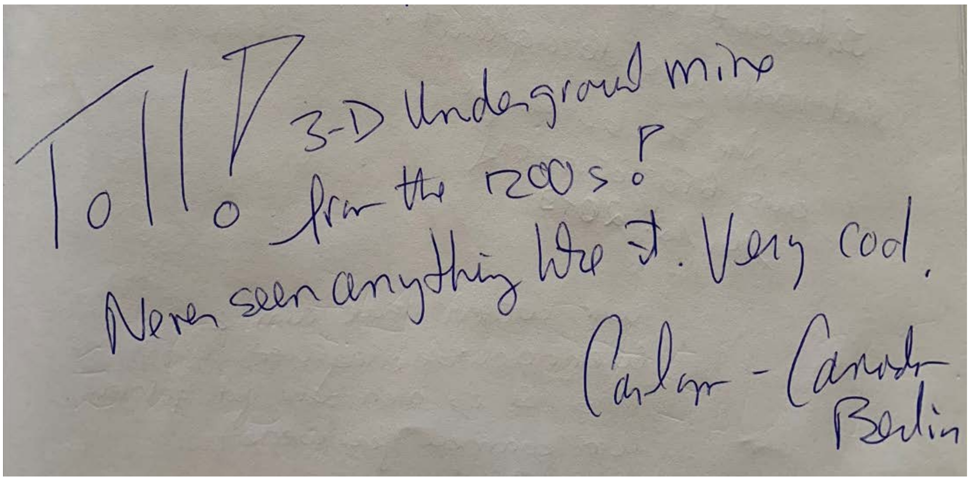

Fig. 18: Guest feedback to the new VR media station in the Museum of Medieval Mining in Dippoldiswalde (photo: L. Burghardt/MiBERZ).

So what is the benefit for heritage actors and managers to create and use the tools of virtual archaeology? Above all, it is attractive (fig. 18). The “modern and coolness” factor reaches especially young people; although – as mentioned above – it is not only restricted to them. It can also be used in museum tours or for educational purposes; it may encourage historical interest or even raise it in the first place. In the case of local and regional museums, it provides a great chance to draw more visitors. Tools like 3D visualisation home kits can make the development of “own” visualisations cheaper and reduce the efforts and costs. By installing VR media stations in museums, tourists will much likely visit small museums in the countryside. Especially for those institutions, the virtual archaeological tools can be a unique selling point. Finally, VR/AR tools can raise awareness, promote the “hidden heritage”, and enhance tourism and regional development in rural areas.

Chapter II

Transnational guidelines for virtual archaeology – some introductory remarks

Computers, as a fundamental tool of modern information technologies, appeared in the mid-20th century, and their influence on modern archaeology can be compared to the impact of the invention of book printing on the formation of modern science. Since the 1960s, when archaeologists began to discuss the theoretical framework of the whole discipline, we got the first glimpses of the digital technology rise against the background of the debate. The first significant contribution to the introduction of three-dimensional space into the field of archaeology was the application of digital panoramic photographs used in the documentation of fieldwork. Another application – the computer-aided 3D manual modelling - was introduced into archaeology only four years later. Actual 3D computer modelling started to be utilised only around the mid-1980s, and projects such as the digital reconstruction of the Roman temple of Bath received massive media acclaim. Based on these successes, Paul Reilly introduced 1991 a new sub-discipline into archaeology, which he called "virtual archaeology." Consecutively, Collin Renfrew defined the purpose of virtual archaeology as the use of the computational potential of computers to visualise and recreate what archaeologists have excavated.

Although virtual archaeology is often presented as a rapidly evolving field, this statement applies more to new digital non-contact spatial data collection technologies such as laser or optical scanning, multi-image photogrammetry etc. than to overall progress. New approaches in computer visualisations, thus, tend to profoundly influence the system of digital data collection and presentation, rather than to establish and solve broader theoretical issues and starting points for the entire discipline. 3D computer-aided reconstruction visualisations are understood as a popular topic of conferences rather than as a standard tool of archaeological research. Therefore, most publications on virtual archaeology still tend to implicitly defend the benefits of 3D visualisations for the field. The implementation of virtual archaeology into broader archaeological practice and theoretical discourses has developed more slowly than predicted. One of the pioneers of virtual archaeology, Donald Sanders (2014, 41), attributes this phenomenon to the general conservatism and caution in introducing new technologies. He corroborates his assumption by the late adoption of photography as an archaeological documentation technique in the late 19th century because sceptics believed that it could not be used for objective scientific documentation. Jean-Claude Golvin takes 2012 the search for the roots of this phenomenon even further and combines a general distrust in visual digital communication with iconophobia, which affects a large part of the scientific community that still prefers written text.

The current state of affairs can be characterised by a bit unfulfilled expectations regarding the purpose of the three-dimensional computer reconstructions, and their virtual presentations. Despite the limitations mentioned above, however, it is possible to present several areas where the use of virtual archaeology plays an irreplaceable role.

The importance of metric 3D recording techniques for the digital documentation and conservation of heritage sites and objects

INTRODUCTION

According to UNESCO, heritage can be seen as a bridge between what we have inherited and what we leave behind. However, world heritage sites (natural, cultural, or mixed) suffer from the effects of wars, natural disasters, weather changes, and human negligence, often with extensive destruction and loss. In recent years, considerable efforts have focused on the conservation of cultural heritage and the documentation, in particular, of artistic and historical works, as well as natural heritage, which has benefited from advances in recording and imaging techniques. Indeed, 3D data nowadays forms a crucial component used to permanently record shapes, dimensions, and volume of essential features and sites in the event of their total loss or for replication, visualisation, valorisation, communication, etc.

The actual technologies and methodologies for heritage 3D recording and modelling allow generating of very realistic 3D results (in terms of geometric and radiometric appearance) to be used for a range of applications such as archaeological (2D and 3D) documentation, digital conservation, computer-aided restoration, virtual reality/computer graphics applications, architectural reconstruction, 3D repositories and catalogues, geographic information systems, visualisation purposes, and more. However, despite all the possible applications and the constant pressure from international organisations to utilise these solutions, a systematic approach of 3D metric recording and modelling in the heritage field has not yet been adopted nor promoted, in particular between the main heritage stakeholders. It is caused by several reasons: (1) The false belief that 3D recording is a “high-cost” technique; (2) the difficulties in assembling accurate and photorealistic 3D models by non-experts; (3) the consideration that 3D information forms an additional process for interpretation whereas 2D documentation is sufficient; and (4) the difficulty in handling and integrating 3D data with respect to other more standard 2D sources. Nevertheless, the availability and use of 3D data opens a broad spectrum of further applications and permits new analyses, studies, interpretations, valorisation, conservation policies, digital preservation, as well as restoration.

METRIC REALITY-BASED 3D SURVEYING

The Venice Charter (1964) states that: “It is essential that the principles guiding the preservation and restoration of ancient buildings should be agreed and be laid down on an international basis, with each country being responsible for applying the plan within the framework of its own culture and traditions”. Although such concept was published almost 60 years ago, a precise, rational, standardised terminology and methodology, as well as accepted professional principles and techniques for the application of digital documentation and presentation, has yet to be adopted.

Furthermore, as stated by UNESCO, “Preservation of the digital heritage requires sustained efforts on the part of governments, creators, publishers, relevant industries and heritage institutions. In the face of the current digital divide, it is necessary to reinforce international cooperation and solidarity to enable all countries to ensure creation, dissemination, preservation and continued accessibility of their digital heritage” (UNESCO Charter on the Preservation of the Digital Heritage, 2003).

The digital documentation and 3D modelling of heritage sites and objects should cover the following steps:

- Metric recording and processing of a large amount of three-dimensional (3D) - possibly four-dimensional, i.e. including time (4D), multi-source, multi-resolution and multi-content information,
- Management and conservation of the achieved 3D (4D) models for further applications;
- Visualisation and presentation of the results to disseminate the information to other users;
- Data access and retrieval through Internet repositories or advanced online databases for digital inventories and sharing, education and research purposes, conservation reasons, entertainment or tourism needs.

The generation of reality-based 3D models (or digital twins) of heritage sites and objects is currently achieved using passive sensors and image data or active optical sensors and range data or traditional surveying (e.g. total stations or GNSS). For architecture, engineering and the construction community, geometric 3D models can also be generated from existing 2D drawings or maps, interactively and using extrusion functions.

Surveying technique shall be selected according to the object dimensions, location constraints, instrument's portability and usability, surface characteristics, working team experience, project budget, and, last but not least, the final goal of the survey. Although people are aware of the potentialities of the image-based approach, including its recent developments in automated and dense image matching, the usability by non-experts and the reliability of the optical active sensor pipeline (with related range-based modelling software) in individual projects is still much higher, although time-consuming and expensive.

There is still no consensus on what technique(s) is better in any 3D recording situation. The commercial market is generally more in favour of range sensors (terrestrial or airborne laser scanners). However, many research projects decide to apply the combination and integration of different recording sensors and techniques, in particular, when surveying extensive and complex sites. Besides the metric performance (i.e. scale and georeferencing), the generation of digital 3D models of extensive heritage sites for documentation and conservation purposes requires a 3D recording technique that can meet the following requirements:

- Accuracy: precision and reliability are two crucial factors of metric surveying unless the work is done for quick and straightforward visualisation;
- Portability: a technique, particularly in terrestrial acquisitions, should be portable because many heritage sites cannot be easily accessed, there is no electricity, there exist local constraints, and so on;
- Low cost: many documentation missions have limited budgets, yet they can obtain high-quality information with relatively inexpensive 3D methods such as terrestrial photogrammetry even when using an amateur digital camera;
- Fast acquisition: most sites have limited time for documentation so as not to disturb work or visitors; and
- Flexibility: due to the great variety and dimensions of sites and objects, the surveying technique should be adaptable to different scales, and it should be applicable in any possible condition.

All these parameters cannot be often found in one technique. Thus, the majority of surveying projects focusing on large and complex sites integrate and combine multiple tools and techniques (fig. 1) in order to achieve more accurate and complete surveying, documentation, 3D modelling, interpretation, and digital conservation results.

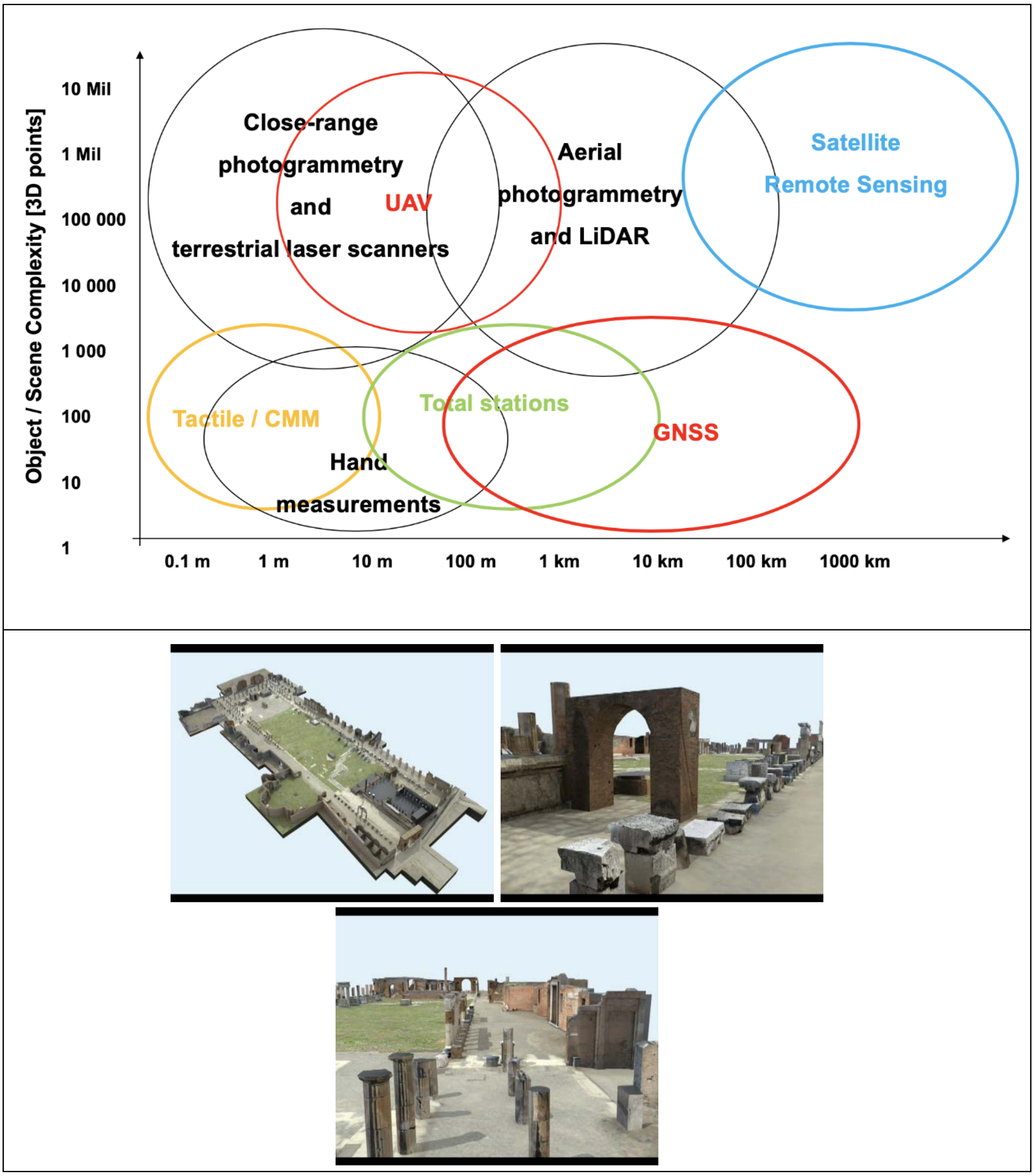

Fig. 1: A schematic representation of all reality-based 3D surveying techniques (above) and an example of a large and complex site documented in 3D by integrating multiple 3D surveying techniques: the Roman Forum in Pompeii, Italy (below). (F. Remondino, Fondazione Bruno Kessler).

DIGITAL SENSORS AND TECHNIQUES

Nowadays, there is a wide range of geomatics data acquisition tools for mapping purposes and heritage digital recording: middle- and high-resolution satellite imagery, large- or medium-format and linear array digital aerial cameras, space and aerial radar platforms, airborne and terrestrial LIDAR range sensors, unmanned autonomous vehicles (UAV) with consumer digital cameras onboard, panoramic linear array sensors, still video cameras, and even mobile phones. Moreover, Global Navigation Satellite Systems (GNSS) and Inertial Navigation Systems/Inertial Measurement Units (INS/IMU) allow precise localisation and navigation. Along with the availability of the wide variety of digital sensors and data, new software has been developed in the last decade, and many automated data processing procedures are now commercially available, in particular, for image triangulation, digital terrain or surface model generation (DTM or DSM), range data registration, and feature extraction. Furthermore, GIS (Geographic Information Systems) and Web-GIS tools, as well as Virtual Reality/Augmented Reality (VR/AR) solutions provide for many new functionalities for (3D) data administration and analysis, visualisation, remote access, valorization and communication.

The continuous development of new sensors, data capture methodologies, multi-resolution 3D representations and visualisation solutions contribute significantly to the metric recording and documentation of heritage and the continuous research in the heritage field, offering new approaches and tools for conservation, valorisation and preservation purposes.

A recording technique is intended as a scientific procedure or sensor (e.g. image processing or digital cameras) to accomplish a specific task (e.g. documentation or 3D reconstruction). At the same time, the methodology represents a group or a combination of techniques and activities integrated to achieve a particular task. Reality-based surveying techniques (e.g. photogrammetry, laser scanning, etc.) employ hardware (passive or active sensors) and software to survey the reality as it is, documenting the actual or as-built situation of a site to represent it from real measurements (fig. 2). Instead, non-real 3D modelling approaches are based on computer graphics software (3D Studio, Maya, SketchUp, etc.) or procedural modelling solutions allowing the generation of 3D data without any particular survey or knowledge of a site and, generally, with no metric results.

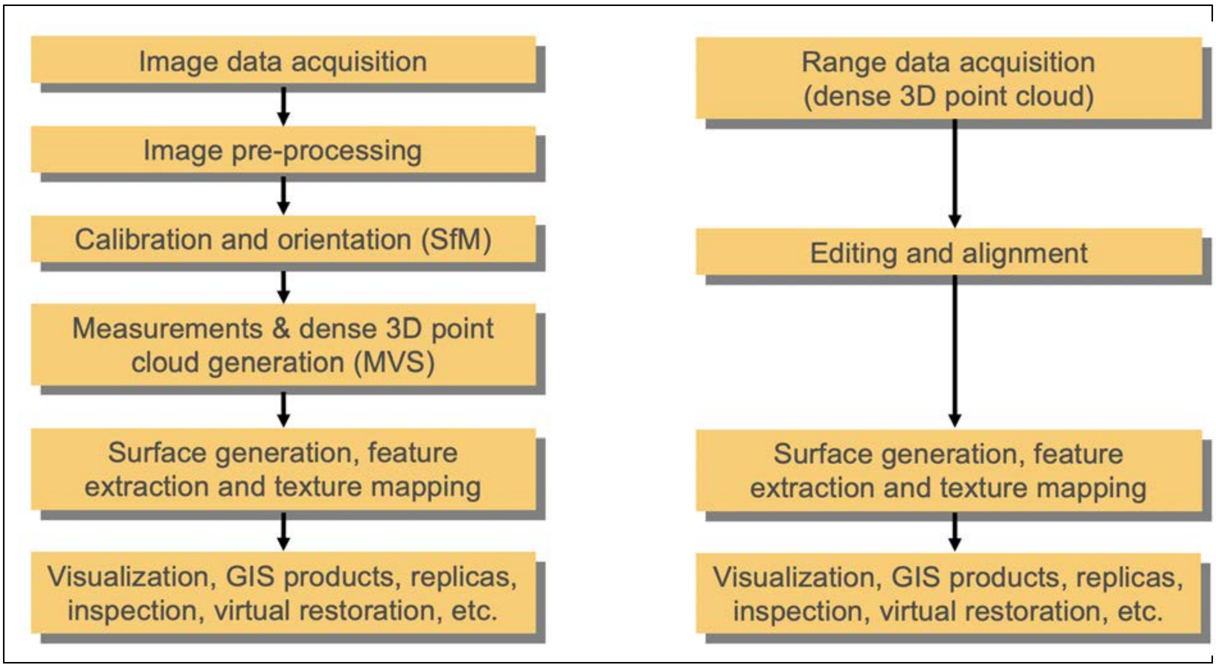

Fig 2: The image- (left) and range-based (right) pipelines with their steps and products. (F. Remondino, Fondazione Bruno Kessler).

IMAGE-BASED

Imaging sensors (like consumer-grade digital cameras, airborne cameras, satellite sensors etc.) deliver image data that require a mathematical formulation to transform the two dimensional (2D) image measurements into three-dimensional (3D) information. Generally, at least two images are required to be acquired from different stand-points, and 3D data can then be derived using perspective or projective geometry formulations. Image-based modelling techniques (Fig. 2 - mainly photogrammetry and computer vision) are generally preferred in cases of lost objects, monuments, or architecture with regular geometric shapes, small objects with free-form shapes, mapping applications, deformation analyses, low budgets, good experience of the working team, and time or location constraints for the data acquisition and processing. Photogrammetry is considered the primary technique for the processing of image data, being able to deliver, at any scale of application, metric, accurate, and detailed 3D information starting from the measured image correspondences (tie points). The correspondences can be extracted automatically or semi-automatically according to the scene and network characteristics as well as project requirements. Photogrammetry can be utilised in different applications like mapping, 3D documentation, conservation, digital restoration, reverse engineering, monitoring, visualisation, animation, urban planning, deformation analysis, etc.

Photogrammetric 3D reconstructions are generally performed with interactive procedures in the case of man-made objects or architectural surveying, where sparse point clouds and few geometries are sufficient to describe the 3D form. Instead, automated image-matching procedures are employed for free-form objects where dense point clouds are required to describe all the object discontinuities and features correctly.

The terrestrial photogrammetric 3D reconstruction pipeline consists of (1) camera calibration, (2) image orientation, and (3) scene 3D reconstruction and rendering. These steps can be performed in an automated or interactive way, according to the type of data, user experience, and project specifications. Accurate feature extraction from satellite and aerial images is still a manually driven procedure, while in terrestrial applications more automated procedures are available. Fully automated methods based on a "structure from motion" (SfM) and multi-view stereo (MVS) approaches are getting quite common in the 3D modelling community, although mainly useful for simple visualisation, object-based navigation, annotation transfer, or image browsing purposes and not for metric and accurate 3D reconstructions and documentation. Indeed, complete automation in image-based modelling is still an open research topic, in particular for the 3D recording and modelling of architectural settings and man-made objects. Today, site recording and documentation can also be performed with spherical or panoramic photography for simple visual applications (e.g. Google Street View, 1001 Wonders, etc.) or metric 3D reconstructions.

RANGE-BASED

Optical range sensors like pulsed, phase-shift, triangulation-based laser scanners or stripe projection systems have received much attention from non-experts in recent years, for 3D documentation and modelling purposes. Range sensors deliver 3D distances directly (and, thus, 3D information in the form of unstructured point clouds) and are getting quite common in the heritage field, despite their high cost, weight, and the usual lack of useful radiometric information for realistic renderings. The collected range data can be used afterwards for visualisation, ortho-rectification, digital restoration, analyses, valorisation and conservation policies, and metric or mapping purposes (fig. 4).

Compared to the image-based pipeline (Fig. 2), the range-based pipeline seems to be faster, but the large amount of data to be processed can generate difficulties and long processing time.

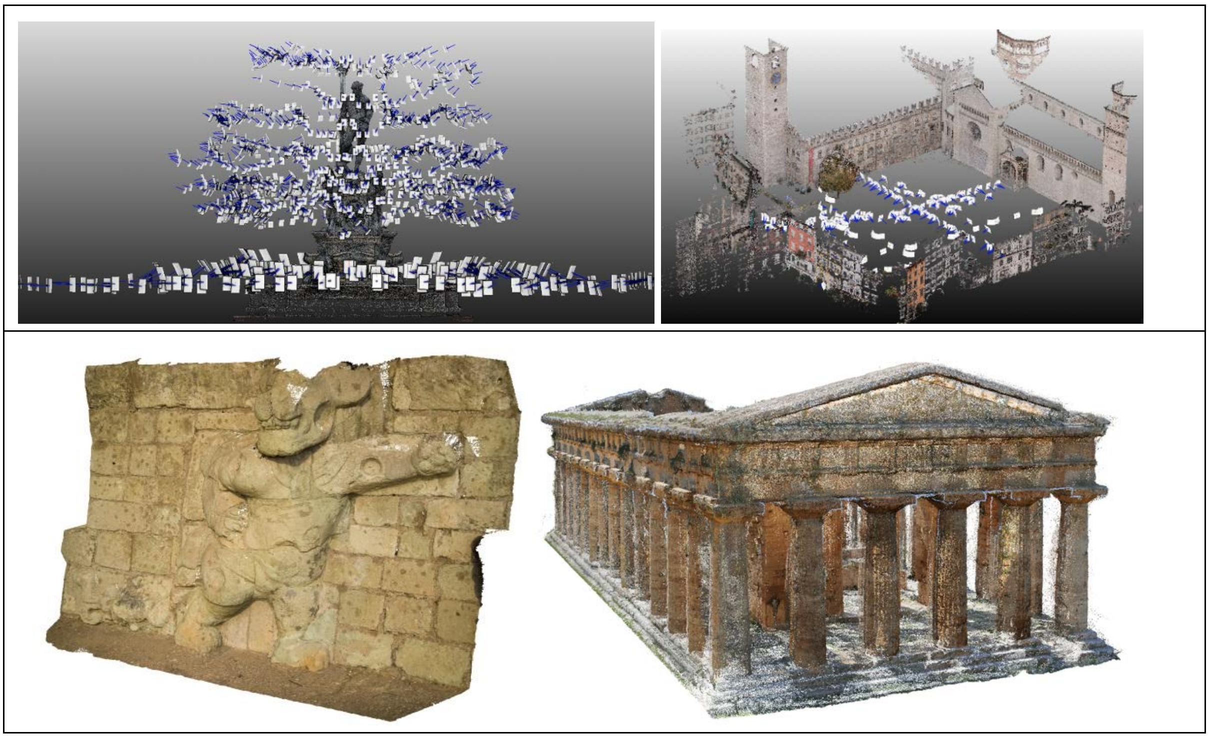

Fig 3: Examples of terrestrial photogrammetric 3D reconstructions, ranging from small artefacts to significant monuments – visualisation with (above) and without (below) the recovered camera poses. (F. Remondino, Fondazione Bruno Kessler).

In the course of the terrestrial survey, the range instrument should be placed in different locations, or the object needs to be moved in a way so the instrument can see it from different viewpoints. Successively, the acquired 3D raw data need to have errors and outliers removed, noise reduction and data gaps filled before the alignment or registration of the data into a unique reference system is performed in order to produce a single point cloud of the surveyed scene or object. The registration is generally done in two steps: (1) manual or automatic raw alignment using targets or the data itself, and (2) final global alignment based on iterative closest point methods or least-squares method. After the global alignment, redundant points should be removed before a surface model (TIN or mesh) is produced and textured. Terrestrial range sensors work from very short ranges, of a few centimetres up to a few kilometres, in accordance with surface properties and environmental characteristics, delivering 3D data with positioning accuracy from a few hundred microns up to several millimetres.

Range sensors, coupled with positioning and navigation sensors, can also be used on airborne platforms (generally called LIDAR or ALS - airborne laser scanning), mainly for Digital Terrain Model (DTM)/Digital Surface Model (DSM) generation, mapping, and 3D city modelling purposes. LIDAR data generally represent a DSM; therefore, for many applications, filtering and reduction are needed to obtain a DTM. According to the flying height and employed sensor, an ALS survey can provide for point clouds with point densities from 1 point/sq. m up to 15-20 points/sq. m. The new ALS sensors allow the storage of multiple echoes of the laser signal ("full-waveform"), and, therefore, offer new potential, in particular, for archaeological identification and mapping of structures hidden below vegetation. Current issues in range-based data processing and modelling that require further development and testing for heritage recording are the automated extraction of features (like man-made objects), the automated alignment of terrestrial scans, and the automated generation of structured 3D data (polygonal meshes) from the recorded unstructured point clouds.

Fig 4: Examples of laser scanning 3D results. (F. Remondino, Fondazione Bruno Kessler).

FUSION

As previously mentioned, the state-of-the-art approach for 3D documentation and modelling of large and complex sites uses and integrates multiple sensors and technologies (e.g. photogrammetry, laser scanning, topographic surveying, among others) in order to:

- Exploit the intrinsic potentials and advantages of each recording technique (Table 1);
- Compensate for the individual weaknesses of each surveying method alone;
- Derive different geometric levels of detail (LODs) of the scene under investigation;
- Achieve more accurate and complete geometric surveying for modelling, interpretation, representation, and digital conservation issues.
-

• Photogrammetry was born ca 1850 • Major developments: 60’s-70’s (bundle adjustment solution); 90’s digital sensors; 2000+ automated methods • Measurement principle: triangulation • Spectrum: mainly VIS • Scale requirements • Redundant measurements / Multi-ray • Adjustment statistics and accuracy values for each 3D point • Established procedures to assess the per-project quality • Problems with illumination and shiny or texture-less surfaces • Typical point density: up to 1:1 of image GSD • No multi-echo or waveform capabilities • XY most accurate than Z (depth)	• Born: ca 1960’s • Maturity: 2000’s with commercial solutions • Measurement principle: TOF (long-range) and triangulation (close-range) • Spectrum: ca 400-1500 nm • Metric data • Single measure, no redundancy • Vendors statistics to evaluate the quality of the data, one value for the entire cloud • Lack of well-defined procedures to assess the per-project quality • Almost independent from light and surface type • Typical point density: 1-25 pts/sqm • Multi-echo and waveform capabilities to filter and classify point clouds • Z (depth) most accurate than XY

Table 1: Main characteristics and advantages of photogrammetry (left) and laser scanning (right).

Three-dimensional modelling based on multi-scale data and multi-sensor integration is indeed providing the best 3D results in terms of appearance and geometric details. Each LOD shows only the necessary information, while each technique is used where best suited. Since the 1990s, multiple data sources have been integrated for industrial, military, and mobile mapping applications. Sensor and data fusion also were applied in the cultural heritage domain, mainly at the terrestrial level, although in some cases integrated satellite, aerial, and ground information for a more complete and multi-resolution 3D survey. The multi-sensor and multi-resolution concept should be distinguished between:

1. Geometric surveying and modelling (3D shape acquisition, data registration, and further processing), where multiple resolutions and sensors are seamlessly combined and integrated to digitally reconstruct features with the most adequate geometric sampling step and derive different geometric LODs of the scene under investigation

2. Appearance modelling (texturing, blending, simplification, and rendering), where photorealistic representations are sought taking into consideration variations in lighting, surface specularity, seamless blending of the textures, user's viewpoint, simplification, and LOD.

Beside images acquired in the visible range of the light spectrum, it is often necessary to acquire extra image information provided by other sensors working in different spectral bands (e.g., infrared [IR], ultraviolet [UV], and X-rays) in order to study the object in greater depth. Thermal IR information is useful, for example, to analyze temperature and moisture gradients within a historic building, often revealing related conditions, alteration, or structure. Near IR is used to study paintings, revealing pentimenti, and preparatory drawings concealed underneath the surface. The UV radiations are instead very useful in heritage studies to identify different varnishes and over-paintings, in particular with induced visible fluorescence imaging systems. All multimodal information needs to be aligned and often overlapped to the geometric data for information fusion, multispectral analysis, or other diagnostic applications.

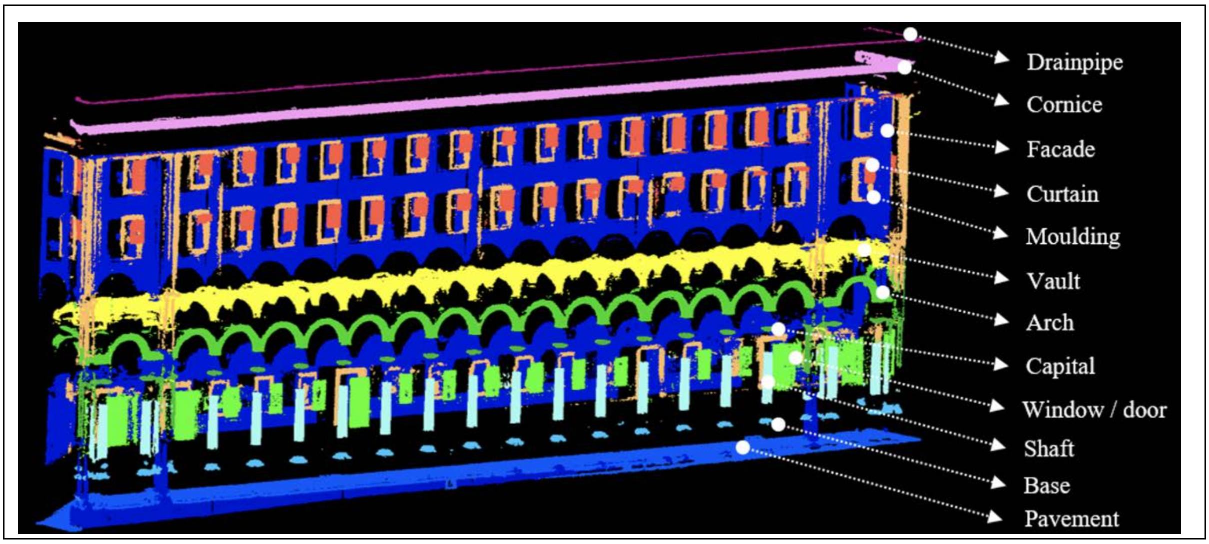

Fig 5: Example of a semantically enriched 3D model automatically segmented with Artificial Intelligence methods. (F. Remondino, Fondazione Bruno Kessler).

CONCLUSIONS

Current 3D surveying and modelling methodologies for reality-based 3D documentation and recording of heritage sites and objects have been presented. The potentialities of the image- and range-based recording techniques have been reported along with different examples at various scales. In the case of heritage, photogrammetry provides for accurate 3D reconstructions at different scales and hybrid 3D models (e.g. digital terrain models plus archaeological structures or surface models with painted layers). Three-dimensional scanners are also a widespread source for 3D data recording in many application areas, although image-based modelling remains the most inexpensive, portable, and flexible approach. For large and complex sites, the integration of images and range data is instead the best surveying and 3D modelling solution. Even though 3D metric documentation is not yet state of the art in the heritage field, the cited examples corroborate the potential of modern 3D recording technologies to digitally document as well as share and manage the information within GIS-like tools. Indeed, the generation of digital 3D models of heritage sites and objects can be followed by further products, applications and studies such as a semantic classification (Fig. 5), web-based visualisation, queries, data sharing or to organize the digitally documented scenes and provide connections between 3D models and 2D databases. The actual image-based 3D documentation approach, together with active optical sensors, GIS tools, and 3D modelling procedures, visualisation and animation software are still all in a dynamic state of development, with certainly better application prospects for the near future. The entire heritage community should better exploit the 3D metric recording domain, as the extra third dimension is generally the added-value that provides beneficial information for immediate long-term conservation and preservation objectives and goals.

LONDON CHARTER AND DATA UNCERTAINTY

The so-called data uncertainty has significantly influenced the creation of 3D digital computer reconstruction models in archaeology. Archaeological sources do not merely reflect the human past, because as a result of post-deposition transformation processes, they have seen an increase in entropy and a considerable loss of information. The significant factors of contextual and spatial uncertainty are, therefore, caused by the type of available data, its completeness, reliability and interpretation. In contrast, in computer visualisations, the main problems comprise geometry and spatial location, age, colour, texture, material, construction, context and landscape. Moreover, in archaeology, it is necessary to receive data from many different sources that have different quality. Thus, the data needs to be quantified as it is often burdened by subjective preferences and decisions of various subjects (persons). The same is true for written and iconographic sources, where the human factor also plays a considerable role. Of course, the lack of data due to the nature of archaeological sources drastically increases the degree of its uncertainty even if some of it can be replaced by.

Fig. 6: Visualization of the reconstruction of the princely funeral on a chariot from the Early Iron Age based on the finding situation captured by SfM, which clearly communicates the difference between real and hypothetical data (image: J. Unger, ARUP).

As early as 1995, Paul Miller and Julian Richards pointed out in their paper entitled straightforwardly "The good, the bad and the downright misleading: archaeological adoption of computer visualization" that the search for new techniques for acquainting new knowledge was not the catalyst for creating three-dimensional computer visualisations in archaeology but rather improving how the existing knowledge can be presented to the public). They were convinced that it was not possible to learn anything new from the created models. The authors also felt, at that time, that high-tech computer models were highly misleading, as the general public perceived them as an image of the real past. The accuracy of the models indicates greater certainty than can be objectively achieved, and in practice, the models display only one correct version instead of several possible interpretations. This criticism was voiced as early as 1991, when the founder of virtual archaeology, Paul Reilly warned that computer visualisations should not become just “nice photographs”. This fear of rendering 3D visualisations to mere art images still prevails and Joan Barceló, therefore, emphasizes 2001 that a virtual model should never be conceived as an end product that is considered an authentic version of the past.

In archaeology, data uncertainty cannot be possibly ruled out as it is always present to a certain extent. In the case of reconstruction models, several hypotheses shall usually be considered. Uncertainty is caused by different types of available data and different ways of interpreting it. Moreover, many assumptions rely on individual opinions only. In the reconstruction model, three areas are, therefore, affected by uncertainty, namely the “shape (geometry, size, spatial location), material (physical form, stratification of buildings), and appearance (surface features)” (Apollonio 2016, 177).

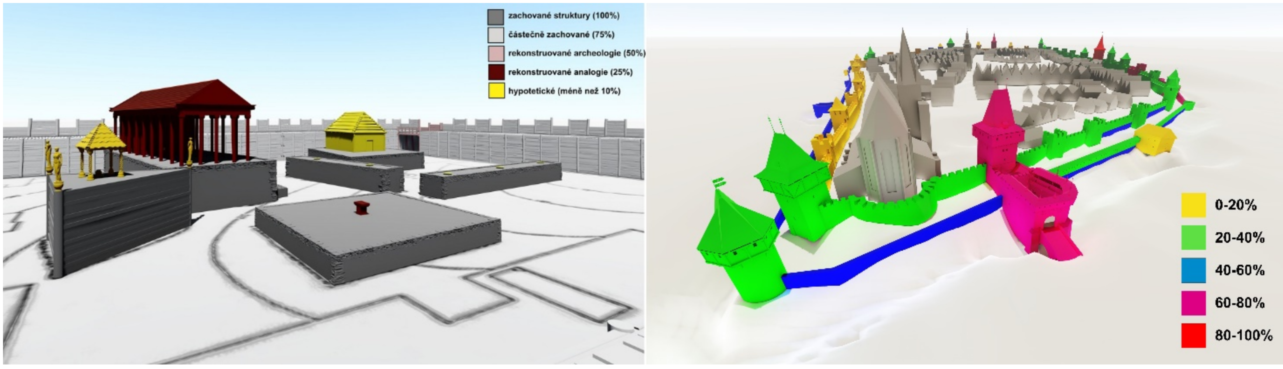

Fig. 7: An example of the usual solutions for the visualization of uncertainty in 3D reconstruction models (on the left the Early La Tene phase of the acropolis at the Závist fortified settlement, on the right the town of Slaný in 1602, Czechia)(graphic: J. Unger, ARUP).

Concerns about the uncontrollable development of computer visualisations led in 2006 to the publication of the London Charter. It was the first tool to establish principles for the use of computer visualisation methods and implement their results in cultural heritage research and communication. In 2011, further principles – the Principles of Seville – were issued focusing on the creation of virtual visualisations, which extend the London Charter. Both documents emphasise the importance of separating real and hypothetical data and the need to use a transparent data process.

3D COMPUTER RECONSTRUCTIONS AS A MEANS OF COMMUNICATION

In the field of information technologies, computer visualisation is a method used to transform symbols into a geometric dimension, and, therefore, allowing to perform further simulations and calculations. A visualisation is, thus, a form that allows us to see the invisible and offer new, unexpected perspectives in scientific processes (McCormick et al., 1987). In addition, if we use features that are too complex, incomprehensible, or exist only in our minds, it is extremely desirable to create their visual models that may help better to understand their construction, organisation, or change. Modelling, thus, creates analogies to realities that do not have a real visual form - in archaeology, they mainly concern multidimensional non-existent structures or features that change over time. Besides, visual communication is a much more effective form than verbal or textual communication because it works faster, in parallel, and many dimensions. The choice of a graphical way of expression can speed up the interpretive process providing a more accessible, precise and concise form of communication. Moreover, because visualisations significantly facilitate the speeding up the whole process of cognition, they are of great importance for use in teaching, science and its popularisation. The acceleration of the cognitive

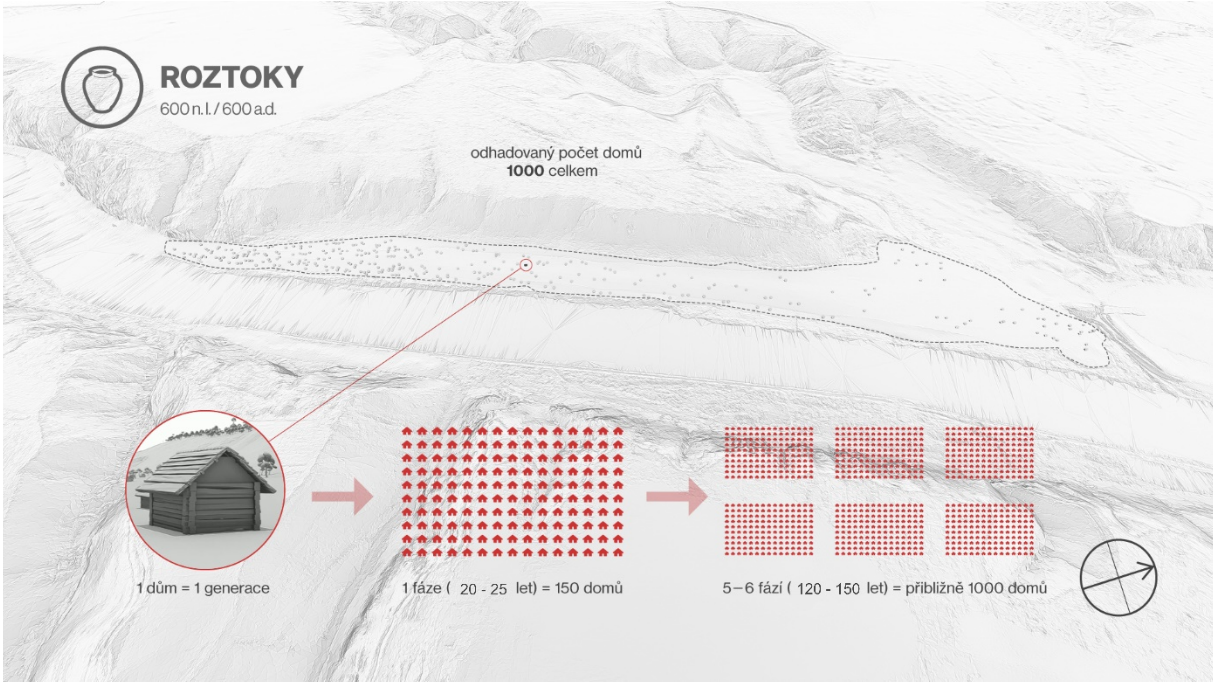

Fig. 8: The combination of 3D computer visualization with infographics provides a quick overview of the entire context of the archaeological site Roztoky near Prague (graphic: J. Unger – S. Kubec).

Due to the issue of data uncertainty and credibility of digital archaeological reconstructions, it is appropriate for archaeology to ideally supplement the visual outputs from 3D reconstruction models by other data specifying the context of the depicted situation. The generated image or fly-through video should not objectively be considered as a final product. Visual outputs from 3D reconstruction models should be combined with other types of data in the form of text, plans, maps, graphs, scales, outputs from 3D digital documentation, etc. Precisely at that moment, the visualisation of the 3D reconstruction computer model gains its full information and scientific potential. This can be achieved by creating a graphic concept with a clear visual hierarchy and a scenario for communicating the necessary information. The output from 3D computer reconstruction should always be considered only as a part of a broader presentation system because the main message and all the information we want to communicate may not be comprehensible from the reconstruction itself. Specifically for visualisations designed for the general public, the output of 3D computer reconstruction has a considerable potential to attract and entice the viewer for a given topic and, thus, naturally lead them to explore the visualisation further and receive additional information about the displayed context. The stylised outputs from 3D reconstruction models offer excellent opportunities to convey information, as they are not bound by the limitations of the real world, they are freer to choose the details and concepts of the image, through the choice of technique, composition and character.

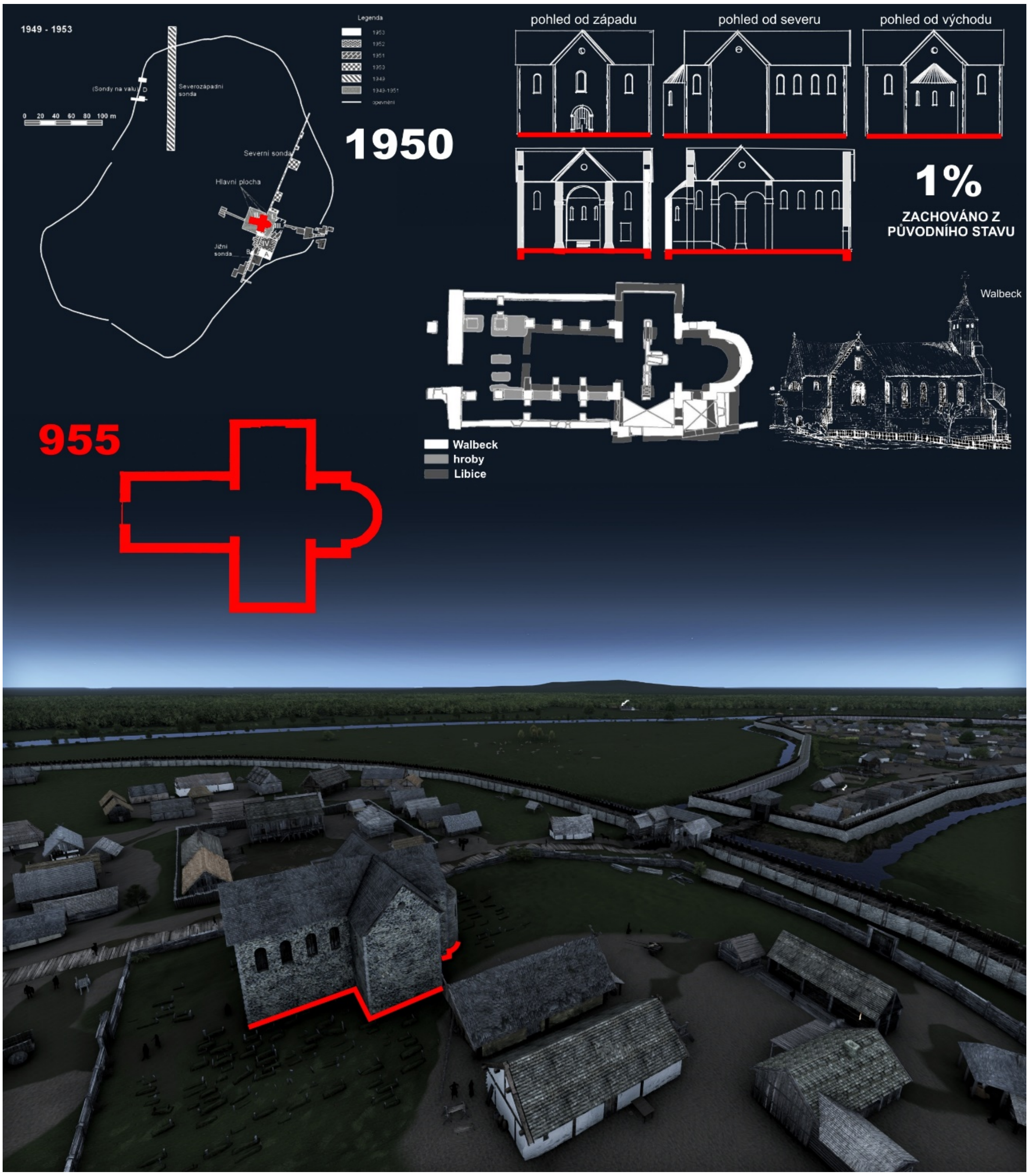

Fig. 9: An example of a more comprehensive 3D computer reconstruction of a church on the acropolis of the early medieval fortified settlement in Libice nad Cidlinou, inviting the viewer to obtain further information about the whole context (image: J. Unger, ARUP).

The targeted use of so-called NPR techniques should play a significant role in the segment of popularisation visualisations. Non-photorealistic rendering (NPR) covers essentially any technique that can transform three-dimensional virtual data into an artistically conceived image. It is the art that is better adapted to the transmission and exchange of information between the author, the depicted theme and the viewer, and it becomes a complex social process influencing the way of cognition. The NPR techniques are also straightforward, but, at the same time, effective methods of corroborating the credibility of the visualisation and purposefully creating better acceptance of imperfect presentations. Thanks to the rapid development in the field of the creative industry, a whole range of graphic tools are nowadays available allowing imitation of artistic styles such as oil paintings, watercolours, line drawings or the characteristic style of technical drawings. The use of such graphic styles is intuitive to visualise uncertainty because they look like drawn by human hand, and the viewer does not have to acquire a new paradigm and interprets the image as they are used to with traditional paintings. The straightforwardness of hand-created images is an attractive form mainly because it targets the viewer's desire to create and entice them on a very personal level.

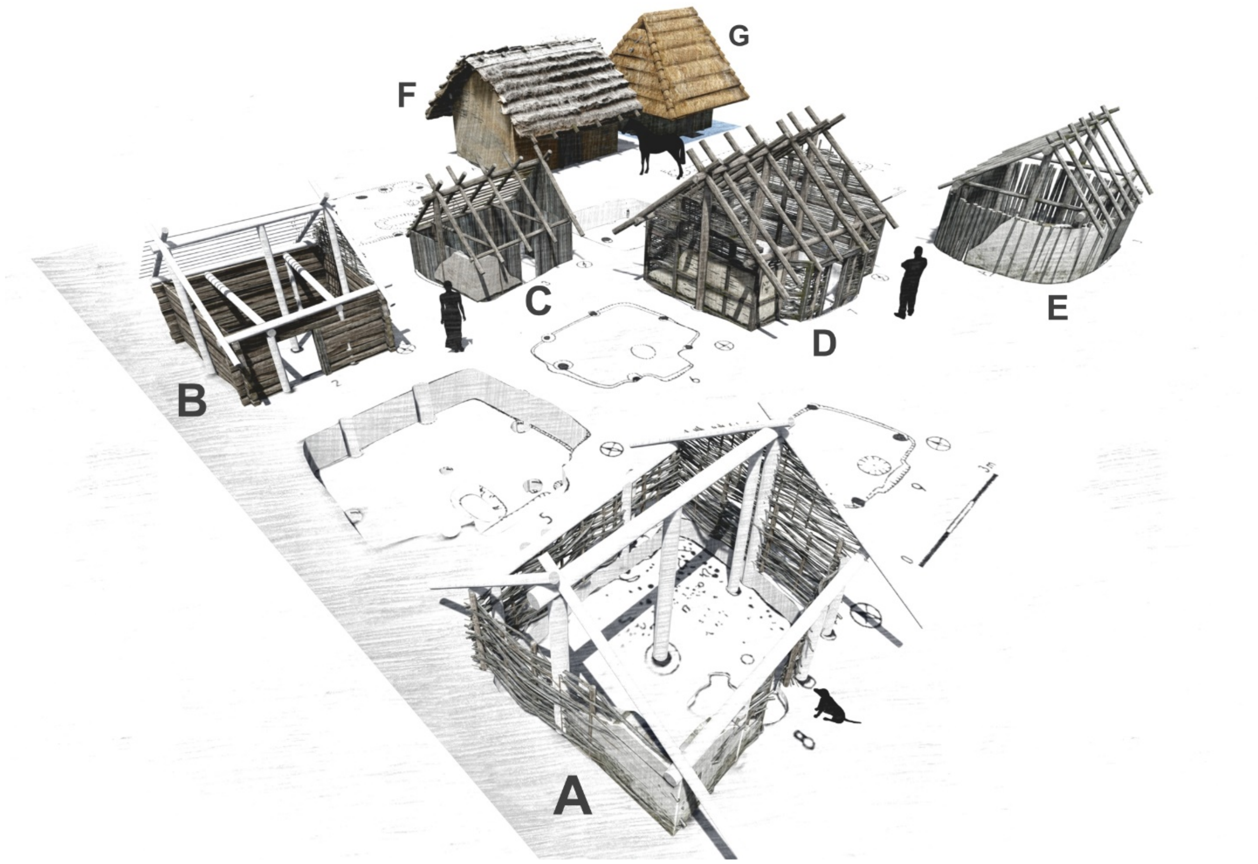

Fig. 10: Computer reconstruction of various types and construction solutions of semi-sunken houses from Roman period in Czechia stylized into pencil drawing (image: J. Unger, ARUP).

The use of NPR techniques can also play a significant role in the professional public, as the artistic rendering of outputs from 3D reconstruction models with its character including a combination of objective and subjective approach, can destabilise the established form of thought processes and show new horizons of insight into archaeological data. The NPR techniques can, therefore, create abstract visual stylisations and, compared to photorealism, have entirely different perceptual properties, as they create an impression of an incomplete image open to further changes. Stylisation clearly states that the image is an artificial, reasoned icon and emphasises easily recognisable elements rather than specific elements. Thus, a stylised image can primarily communicate on a formal, universal and neutral level by abstracting from the features of the object precisely its essential characteristics. Avoiding aesthetic and personal experience in creating visualisations can, thus, be irrational, and the “dehumanisation” of the representations of the past may not be seen as a productive solution.

Fig. 11: Early La Tene phase of the acropolis at Závist near Zbraslav stylized as an oil painting (image: J. Unger, ARUP).

CREATION OF 3D COMPUTER RECONSTRUCTION MODELS

Currently, the main issue does not represent the technical side of modelling, as several specialised graphic softwares allow sophisticated computer modelling (Blender, SketchUp, 3ds Max, etc.), but rather the issue of the methodology of their creation. When creating a computer reconstruction, the author of the model must make a huge number of immediate decisions, each relying on many factors and despite knowledge of technical or historical nature or physical laws, the decision-making process is often influenced by a "gut-feeling" indicating what is right at the moment and what is not. The creator should, of course, be as aware as possible of the reasons for some of their decisions in order to review their validity, but the question is what level of detail of the decision-making made in the interpretation process is realistic at all.

From the very nature and character of the reconstructed situations, it is clear that maintaining both professional and technical quality is rather challenging. On the one side, the highest possible historical transparency is required while, on the other side, the creator needs to achieve the top quality of the model. The author should know not only historical and archaeological realities, a variety of technical details concerning the computer 3D modelling, but also be able to understand semiotics, processes and relationships in the perception and interpretation of visual and verbal sources. The creation of computer visualisations also requires at least the essential art of creating images, i.e. knowing how to achieve aesthetic values and dynamics, how different shapes, colours and textures may influence the representation of ideas, how to convey a higher form of a message or how to evoke emotional reactions. Thus, it is evident that for the creation of complex 3D computer reconstructions on a larger scale, a single author is not enough and cannot in a reasonable short-term time contain everything. Therefore, if we do not want to compromise the resulting quality in any of the aspects, the optimal form of cooperation is a larger team, where different people focus on preparation and interpretation of scientific documents, sketching concepts of the environment and objects, creation of professional 3D graphics. At the same time, others concentrate on the preparation of outputs that convey visually, as well as graphically, correct (or even prepare the script, should the output be a video). Even in this case, however, it is necessary to take into account the tremendous time-consuming nature of the entire process, and computer reconstructions of important archaeological sites usually arise in the framework of longer-term projects.

Fig. 12: 3D computer reconstruction of medieval mining area in Utin (Czechia) acting as an incentive to download the mobile application about the site (image: J. Unger – M. Kocourek – M. Kostal – M. Vagner).

Since this field requires technical knowledge and a high level of computer modelling, the historical accuracy is usually discussed when the computer visualisations are finished. However, such approach more-or-less means the post-hoc justifying of creation process rather than developing more permanent methodologies and manuals. Due to many meanings that the image can evoke, in the academic sphere, we often see the marginalisation of the role of computer reconstruction models in research, because it is difficult to control their creation directly. Therefore, they destabilise the scientific assumption of objectivity and direct replication.

SIMULATIONS IN A DIGITAL ENVIRONMENT

Visualisation is, in essence, a rather complex set of different relationships and correlations, but this is what makes it a powerful empirical tool. It corroborates the way how each applied form and type of data used influences other sections of the knowledge base and data within the framework of the process of creating a model. At this level, computer reconstruction functions as a tool for testing hypotheses. The environment where visualisations are being created gives us the freedom to try different possibilities and dynamically test them while relying on various digital variables. It is, thus, possible to support various interpretations, each of which represents one of the possible stories that can be told about our past. If the model creation process uses reliable sources, it allows the author to present highly speculative hypotheses and experiments. Well-documented visualisation is not only a driving force for hypothesis testing, but can also influence attitudes toward the nature, goals, and methods of cultural heritage research and communication. The most important fact is that the number of possible updates to the virtual environment is unlimited, and we can never completely consume it by using it. Virtuality is an inexhaustible resource.

Fig. 13: Phasing of one of the possibilities of construction of a long Neolithic house visualized on a 3D SfM model (images: J. Unger, ARUP).

Attempts to gain new pieces of knowledge through virtual reconstructions are, however, relatively infrequent, and there are considerable reservations about such an approach in the scientific community. This may be related to general doubts regarding the credibility of virtual reconstruction models as a form of scientific evidence. Should, therefore, be virtual reconstructions assessed as a research tool, their epistemological function must be specified in the first place, which requires a very well-formulated research question or hypothesis that can be confirmed based on qualitative or quantitative data obtained from the virtual environment.

Fig. 14: Example of changes of 3D reconstruction model after consultations with the head of excavations in Msecke Zehrovice (Czechia), where the famous stone sculpted head from La Tene period was found (images: J. Unger, ARUP).

Based on the current discourse of research applications in the virtual environment, it is clear that the discussion focuses on the issue of whether computer simulations can replace reality. However, such direction of the debate is an entirely unproductive, as current technological possibilities preclude the creation of a completely sophisticated and functional virtual environment. Ir would be more appropriate to design targeted and focused research tasks. Such approach eliminates the need to create virtual models with the highest possible degree of realism or interactivity, and the virtual environment can be functionally created from the beginning to answer specific questions, which triggered the model creation in the first place. A strong motto that the virtual environment already provides is the possibility of repeated simulations of natural properties (physical laws, spatial limits, construction parameters, etc.). The untapped analytical potential of 3D computer reconstructions also lies in the fact that a model that could be used for simulating various physical properties requires application of a more demanding approach and knowledge of working in more sophisticated modelling software than when you want to create a model intended only as visualisations.

CONCLUSIONS

Digital reconstruction modelling and visualisation can act as suitable catalysts for general archaeological interpretation, as their creation raises a unique set of questions that would not otherwise be explicitly apparent. The possibility of creating computer reconstructions and rendering an unlimited number of variants of various situations may serve as a very dynamic tool directly integrated into the process of analysis and interpretation of archaeological data. Moreover, the possibilities of visual communication, provided by computer graphics for the presentation and promotion of the field also function as a fundamental aspect. Reconstruction, as well as a direct interpretation of the past, is a critical factor in making it accessible to today's people. Visualisation of the past in a virtual space with all the possibilities described above certainly has significant lasting potential.

Chapter III

Case studies – Mining Archaeology

Mining has a very long history in Europe. The first underground extraction of raw materials can be traced back more than 20.000 years ago. Mines used to extract the red chalk were discovered on Thasos (Koukouli-Chrysanthaki). The history of mining, therefore, began with minerals that were very probably used for rituals. Later on, gemstones and flint were also mined. Mining provided raw materials used for tools and various equipment. From the Chalcolithic Period (Copper Age, 4th millennium BC) onwards, mining was responsible for delivering ores used for metal-smelting. Without mining, there would be no jewellery, tools or weapons.

In addition to such dominant importance, since the 2nd millennium BC, metal gained the function of means of exchange and payment. Without silver, gold and bronze, no economic exchange would have been possible starting from prehistoric times until the 19th century. The early silver mines in Laurion (GR) are as much a witness to this development as the medieval mines on Monte Calisio (I). The mining of iron ore, which began in large stalks, provided the raw material used for railways, the automobile and armament industry. Since the mid-19th century, metals have gradually increased their importance in the building industry and found their current peak in the glass-and-steel constructions in the big cities.

Mining has accompanied Europe through the last tens of thousands of years. It has made a decisive contribution to the development in many areas. The importance of mining led to large-scale prospecting for ores and minerals in the entire Alpine region and many other regions more than 3.000 years ago. If the exploration was successful, mining often triggered inhabiting and development of remote areas. Mining has, thus, permanently changed the entire regions of Europe.

The proceeds of metals and minerals contributed to “wealth” of a particular part of society as early as the Stone Age, as the oldest gold finds in Europe suggest, currently kept in the Varna museum (Bulgaria). The graves in prehistoric Hallstatt bear witness to the importance of mining as well as the prosperity of the Early Modern era, for example, in Salzburg, Trento or Dresden. Without the production or transport of salt or silver, these three cities would not exist in their current form.

MINING TODAY

Before it was very easy to transport ores, metals and minerals in large quantities by trains, ships or trucks, people tried to utilise raw materials in their vicinity. Over the past decades and centuries, many European mining regions have been closed down. Extraction has been moved to other parts of the world where the production and labours costs, as well as legal requirements, are lower.

As important as the mining was in the last millennia in Europe, so insignificant it is today. As a result, the mining nowadays represents only a marginal phenomenon, except for opencast mining for coal; almost no miners are trained, and the dwindling few mine minerals or ores. This trend stands in direct opposition to the fact that more ore, metals and rocks are being extracted, produced and consumed than ever before. Without mining, there would be no resources for all mobile phones, cars, aeroplanes, batteries, wires etc. The historical progress briefly described above has led to the fact that even though the mining industry was decisive for the development of Europe and currently forms the basis of our mobility and communication, it is no longer anchored in our consciousness.

VISUALISING MINING

As Sören Kirkegard said: “Those who do not know where they come from do not know where they stand and even less where they are going. Life can only be understood backwards, but can only be lived forward;” it is of utmost importance to know the history and development of mining in order to be able to shape our future.

In order not to let the mining in Europe and its importance for European history be forgotten, as well as not to lose sight of the problems of the current ore and raw material extraction, it is necessary to visualise the still existing mining relics.

Challenges

Although the importance of some mining regions has been recognised by the UNESCO Commission (Hallstatt, the German-Czech coal and metal region Erzgebirge / Krušnohoří and the Stone Age flint mine in Krzemionki (Pl) were enlisted in World Heritage Site List), it is still complicated to explain mining.

Fig. 1: Hallstatt High Valley with its archaeological sites (image: D. Brandner, NHM Vienna).

The challenges are manifold: Traces of historical or prehistoric mining activities are usually quite hard to identify and are often located in remote regions. These traces are either hidden deep inside mountains, such as in Hallstatt, on the Mitterberg near Bischofshofen/Sbg, or they are covered by undeveloped forests such as at Mt. Calisio near Trento (IT). Other sites have undergone rapid urban development, and are currently hidden beneath modern buildings such as Dippoldiswalde (DE). The heritage site lies more 8 to 30 m deep under the houses and is completely concealed from the world above the ground. And last but not least, some sites are too inconspicuous to be recognised as all – such as Utin (CZ).

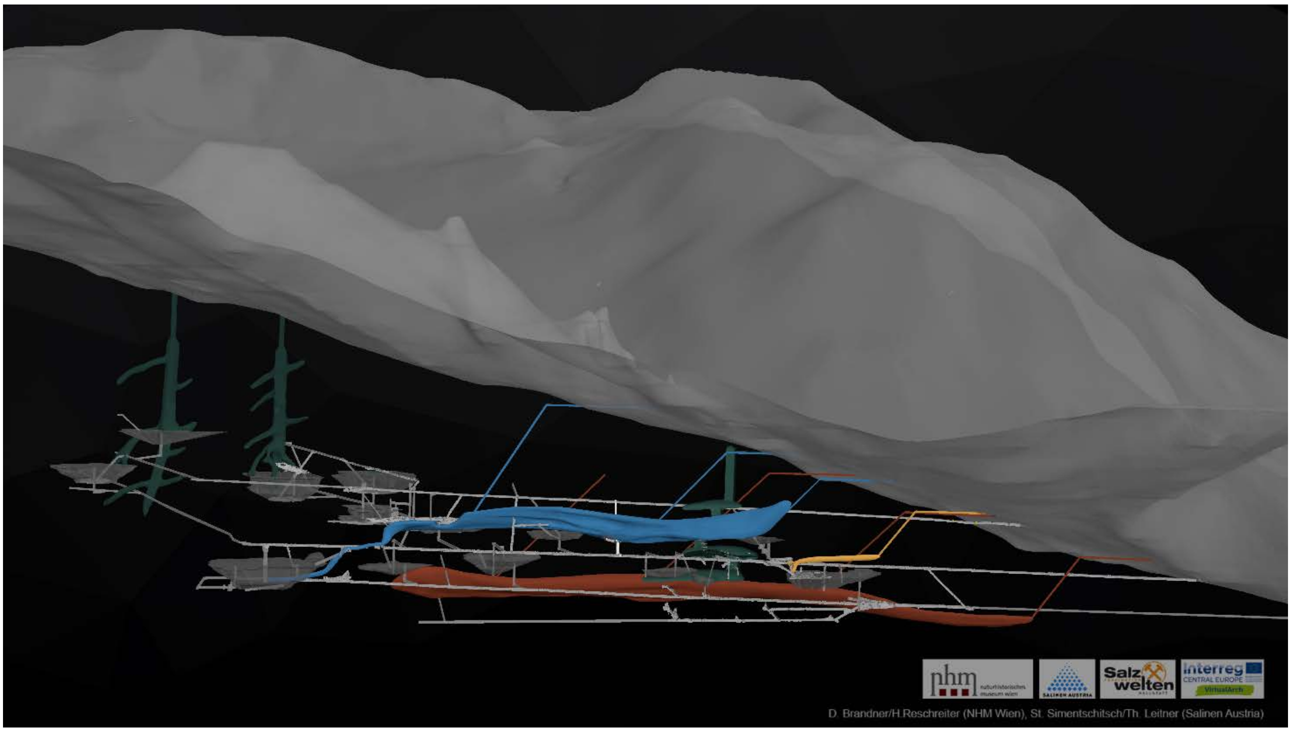

Fig. 2: Archaeological sites in Hallstatt lie deep underground (image: D. Brandner, NHM Vienna).

Methods to be used for documentation

Before the mining relics can be communicated, detailed documentation is necessary. Here too, the challenges are manifold as far as underground, as well as above-ground, mining relics are concerned. The difficulties of working inside mountains are often immense. Space there is usually narrow, dark, humid; in other cases, the cavities are too broad, and it is not always easy to establish a connection to the surveying network. Traditional surveying and documentation methods are used, as well as 3D laser scanning and image-based modelling. To apply the last-mentioned tool, it is necessary to take thousands of pictures under the confined space conditions.

Fig. 3: Mining archaeologists surveying and documenting the underground heritage. (© Archaeological Heritage Office of Saxony; photo by M. Jehnichen).

Fig. 4: Pictures taken for image based modelling. Thousands of shots are necessary (photo: C. Fasching, NHM Wien).

The documentation of surface mining traces is usually also quite challenging. They often cover vast areas and are located in impassable landscapes full of dense vegetation hindering the documentation. Due to remote locations, any comprehensive survey or collections are subject to intensive preparatory work. A wide variety of techniques can also be used above ground: aerial photographs, airborne laser scanning, image-based modelling based on drone images, and geophysical methods, such as geomagnetic, georadar, etc.

Methods to be used for visualisation

Any visualisations and communication of past mining activities rely on accurate archaeological documentation. However, the impartation of the old mining activities poses significant challenges to the mediators. As mining is almost extinct in Europe, the target audience has no concepts or ideas about how to perceive the underground world. Therefore, there are only a few points of contact, where impartation and interaction can start.

Fig. 5: Information board at Monte Calisio, Italy. (photo: Autonomous Province of Trento, Cultural Department)

It is therefore of utmost importance to utilise anchor points in the field to launch any impartation tour. These anchor points can be placed at signposted hiking trails through former mining areas, on display boards in mining towns or on specified markers used for Augmented Reality (AR) application. For example, in the Monte Calisio region, twelve small panels are distributed along the trails (fig. 5). Each stop signifies that the tourist has arrived at a Point of Interest (PoI). There, the appropriate mobile application provides digital data, and the visitor can learn about that particular PoI.

I. <u>Augmented Reality</u>

The AR technology allows us to locate and impart completely invisible mining relics in the terrain. For example, the Archaeological Heritage Office of Saxony has developed a specialised application (only for Android-based devices) for the medieval mines in Dippoldiswalde (fig. 6). By using it, users can examine formerly existing shaft entrances to the world beneath the ground or walk virtually through a reconstructed medieval tunnel and meet medieval miners at their hard work.

Fig.6: Screenshot of the AR-App with a virtual mine entrance on the display as access to discover and experience the mining world underneath Dippoldiswalde (Ch. Lobinger, Archaeological Heritage Office of Saxony).

Additional information boards about mining archaeology and related topics (such as the town history) have been prepared and installed nearby these “spots” in the course of another project.

II. 3D models and other media

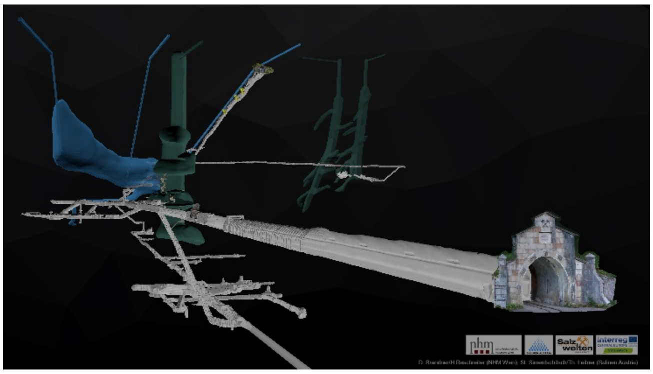

Fig. 7: Visualisation of a part of the modern tunnels and prehistoric sites with reconstruction of the Bronze and Iron Age galleries (D. Brandner, NHM Wien).

In addition to such “location-bound” impartation channels, which only make sense in the mining area itself, digital visualisation methods such as Virtual Reality (VR), 3D modelling, and mobile applications have opened up further digital communication options, which can be utilised at any time and any place. These media allow historical mining and all its facets to be presented and communicated in a variety of innovative ways. They range from a virtual flight into mining galleries that are otherwise inaccessible to exploring mines by using VR and historical-themed games.

In Hallstatt, work is in progress to make the underground sites experienceable through virtual journeys into the mine. In recent years, a large part of the gallery system and the archaeological areas has been scanned or documented using image-based modelling (fig. 7).

Sketchfab is another platform for transferring the underground mines, as well as specific mining relics such as equipment and tools, in the 3D environment.

III. Virtual Reality

Fig. 8: Museum visitor at MiBERZ during a "workshift" as a medival miner (Ch. Lobinger, Archaeologica Heritage Office of Saxony).

In addition to the virtual mine tour briefly mentioned above, VR facilitates to revive historical or prehistoric mining with all its equipment and activities and to dive into a world long gone. In 2019, the Archaeological Heritage Office of Saxony decided to develop and establish a VR media station in the Museum of medieval mining (MiBERZ) in Dippoldiswalde (fig. 8).

Although wooden tools and fixtures can be often found in mines, and, it is, therefore, possible to reconstruct the actual operation; the VR technologies still enable to add many details such as clothes and tools of the medieval miners or fascinating information on their living conditions.

To provide a realistic picture, a realistic reconstruction has to be created (fig. 9. To do so, one still needs to gather a lot of information and answer many questions, for which there is not enough scientific data available. For architectural reconstructions, suggestions have already been mentioned regarding the probability of reconstructions. It would also make sense to create similar visualisations and reconstructions of other archaeological virtual communication channels so that the power of the images does not give a false impression that everything depicted can be proven. For the mines in Utin and Hallstatt, for example, the world of the historical and prehistoric miners was reconstructed in great detail and converted into the VR environment.

Fig 9: VR reconstruction of the Bronze Age mining in Hallstatt (I. Slamar, Scenomedia).

Based on the VR data, it is also possible to use archaeological content for games and encyclopaedia entries, i.e. for entertainment and education. As an example, the game "Buchberg 1269" that was created for the site of Utin can be named. The mobile application was developed for OS Android. It was divided into two main sections – the game itself, and an Encyclopaedia. Both parts were complemented by 360° panoramic views, interactive 3D models of artefacts, and Augmented Reality approach. Thus, the mobile app users can enjoy a virtual tour through a vibrant medieval mining town with its mines, objects, houses and above-ground workplaces such as ore mills, taps and metallurgical facilities with furnaces and kilns. Information in picture and text complete the virtual journey.

Fig 10: Printscreen from the Encyclopedia section of the application (left – every pages contains information about Point of Interest and additional pictures, photos, plans etc., right – by clicking on the 360° sign, the user can enter virtual reality view) (image: J. Unger, ARUP).

To involve the general public even more, a virtual "thriller" game was developed as part of the application. It is called Ďáblova štola (Devil's Adit) and begins in the year 1269. The player takes the identity of the fictional character of the knight Jacob von Zaun. Jacob meets various historical personalities, which are attested in written sources of the 13th century in connection with Buchberg.

The VR in Hallstatt is set up so that it is possible to switch the application to a separate "researcher" mode and obtain background information on the images displayed.

CONCLUSIONS

The vast number of different visualisation options make it possible to convey historical and prehistoric mining activities both in the former mining districts itself and on the Internet in a very vivid way and accompanied with a wealth of information. The history of the regions and their development can be told. By increasing awareness regarding old European mining tradition, past raw material production and its consequences can be thematised. Moreover, the current supply of raw materials can also be brought into focus in entirely different contexts, such as long-standing issues regarding long transport routes, large-scale environmental destruction, and exploitation of primary producers.

Many old mines cannot be visited by visitors because it would be too dangerous to drive or walk through them, or because, as in Dippoldiswalde, for example, they have to be sealed off for safety reasons.

Procedures presented here make it possible to visualise the otherwise inaccessible areas and make them experienceable. The users can learn about them and, thus, become aware of them. The perception of the old mining industry by the public and stakeholders makes it easier to launch any suitable measures for the protection and preservation of archaeological sources.

Just as the mining functioned as a trigger to open up many regions, the successful mediation of the mining relics can promote the utilisation and regional development of these mining landscapes through tourism. The situation in Dippoldiswalde, for example, has clearly shown that Virtual Reality and providing digital virtual tools to locals as well as tourists can improve even small museums like the MiBERZ as they can establish themselves more successfully as a leisure time facility. It raises not only the awareness of the cultural heritage in their region but also promotes regional development (through tourism and gastronomy).

The utilisation of mining remains through tourism is currently one of the few opportunities for regional development in many regions. As positive as tourism can be seen in this aspect, it can consecutively endanger the cultural heritage itself. The better tourism develops, the more infrastructure must be provided to cope with the influx of visitors. The infrastructure construction, however, often involves intensive interventions in the soil, which in turn, if not carried out very carefully and planned, is harmful to the mining remains hidden beneath the ground. Apart from the utilisation for regional development, many of the outlined visualisations are also of great interest for research. Thus, the 3D data available on the net serve as a basis for further investigations.

Case studies – Underwater Archaeology

Underwater research is a rapidly developing field of archaeology. Even though it is still developing, the introduction of modern documentation methods has occurred only recently.

These methods allow archaeologists to produce persuasive visualisations, which can be used in archaeological research, but also for its presentation to the general public. Archaeological sites located underwater can be visited only by a minimal number of visitors with the appropriate skills and qualifications. Even people with the required qualifications often have limited access to underwater archaeological remains due to their location and depth. Therefore, creating visualisations should be one of the priorities of modern underwater archaeologists.

Archaeological features such as wrecks, submerged settlements, harbours, and many others can be unusually attractive for the general public. Preservation of organic materials at these sites is much better than on dry land (fig. 11). Because of that, we can obtain more archaeological information and consecutively, prepare more appropriate visualisations.

Fig 11: 3D model of underwater trench (image: P. Stencel, UMK).

One of the most pressing challenges of modern archaeology is the issue of public awareness. On the one hand, the awareness should be developed with the help of a broad system of dissemination of knowledge, but on the other hand, effects of such action can be better protection of archaeological heritage. Based on the aforementioned, public awareness can significantly benefit from modern visualisation techniques. It is also worth mentioning that underwater archaeological sites are often associated with important historical events of regional or even national impact. Such places (archaeological sites), also attract local activists, governmental and non-governmental organisations, which should be considered “target groups” for presenting the visualisations.

CHALLENGES

There are many challenges for archaeologists who conduct their research in the aquatic environment. First of all, making the right 3D documentation that allows us to create visualisations is much more complicated there than on land. The essential requirement is proper sealing of devices for taking photos in terms of 3D documentation while ensuring access to their adjustment. Starting from cameras, through lighting to more complicated devices, they all must be adequately sealed so that they can be used underwater.

Fig 12: Underwater documentation of archaeological heritage (photo: Powodna).

Limited visibility represents another issue. A large part of 3D underwater documentation methods such as photogrammetry is based on optics. Therefore, adequate underwater visibility must be ensured in order to use such recording methods. If it is not possible to increase the lighting, camera resolution must be adjusted. Natural conditions have a significant impact on visibility, primarily sunlight, depth, the intensity of water movement, and the degree of vegetation at the bottom of the basin.

The last, but probably the biggest challenge of underwater 3D documentation is the proper training and skills of the researcher who performs it. These skills should concern not only the preparation of the documentation itself (Fig. 12) but also require extensive diving experience. An underwater archaeologist performing such activities should have extensive skills of underwater movement and buoyancy control; otherwise, they can make a task of digital documentation much more complicated and even impossible. Therefore, it is imperative to properly train archaeologists in diving and facilitate their continuous training, allowing them to develop good habits and accumulate experience.

RECORDING METHODS

Underwater photogrammetry

Advantages of photogrammetric documentation in an underwater environment made this method one of the most popular technique to record submerged cultural heritage. It has been applied on many underwater archaeological sites, and it is clear that photogrammetry provides a relatively quick and easy way to obtain precise data that can be used to create detailed 3D models of submerged structures.

Easy to use photogrammetric software and simple principle of the method itself – “make images to obtain data” – has led to the conclusion that after a quick introduction, almost everyone can use photogrammetry, even without proper knowledge and experience. It is true. It is amazingly easy to get some results from such an underwater survey. The question is: "Are any results good enough for scientific research?" Nowadays, photogrammetry is not a new method in underwater archaeology. This technique needs standardisation for maintaining a decent quality of scientific documentation.

Restrictions concerning hardware and software usage seem not to be a proper way to set up good standards as the technology develops very fast, often in unpredictable directions. The same applies to any restrictions concerning 3D model face count, image resolution etc. The goal of photogrammetric documentation should be obtaining the best possible quality images of archaeological data. The quality of data mirrors in the model and images resolution and varies tremendously depending on the subject of documentation (fig. 13). For example, a single find of pottery documented in situ can have much higher pixel to meter ratio than architectural structures documented in a vast harbour area. Image count and overall resolution may also vary according to water visibility conditions. Because of those reasons, standards for underwater photogrammetric documentation should take the form of a list of good practice and guidelines instead of strict technical restrictions.

Fig 13: Photogrammetric documentation of medieval longboat (image: F. Nalaskowski – P. Stencel, UMK).

Equipment

Theoretically speaking, a better camera shall provide better images, and, therefore, better data for photogrammetry. In practice, high-end photographic equipment can help us in difficult visibility conditions, but it is not necessary to gather proper data in a bright and clear water environment. Even sports cameras can be the right solution for some underwater photogrammetry projects. The only restriction is that the user must have full control over camera shutter speed, aperture (if adjustable), ISO rating, and white balance. Collecting images in “automatic mode” is unexpectable as it can cause blurriness, and differences in image brightness and colour. It is a good practice to use artificial lights connected to the camera because they can help to lighten up nooks and reduce shadows on documented features even in bright conditions. Underwater video lights, in that case, are a much better solution than flash/strobe lights. The usage of zoom is unacceptable.

Site preparation

In most cases, preparation of the underwater site for photogrammetric recording takes more time and effort than data acquisition. What is not visible on images will not exist in the documentation. With that in mind, archaeologists should prepare the site for pictures by cleaning the artefacts from loose sediment and vegetation. Documentation tags should be visible and, if possible, face upwards. The site should also be tagged with georeferenced markers to record the exact position of the documented area. If for some reason, precise georeferencing of the markers is not possible (water depth, distance from the shore, etc.), the site should be referenced locally. It means that with the help of levelled markers with measured distances, we can determinate X, Y and Z axis for the site. Without that, it is impossible to create any proper top view of the site. If the markers for the local coordinate system are placed correspondently to the directions of the world (with the use of diving compass), then acquiring GPS position and water depth of the “0” point can help us to localise the site in geographical system approximately. Whether the site is referenced geographically, locally or for some reason, it does not need to be referenced at all; it always must be scaled appropriately. To scale the site, at least one scale bar must be placed inside or next to the documented area.

Data acquisition

Still images have, without any doubts, better quality than movie frames captured with the same device. However, video recording for photogrammetric documentation gives the flexibility to choose how many images will be used in the process. Recording video is also more comfortable and faster but unfortunately not good enough for difficult visibility conditions. Images can be gathered by a diver, ROV, AUV or even a boat with a submerged camera. The latter method provides the opportunity to use GPS antenna for georeferencing; it is, however, useful only in shallow and calm water. Camera settings must be adjusted accordingly, the light conditions and movement speed in order to obtain bright and sharp photographs or video frames. Such a simple rule is the very foundation of proper photogrammetric documentation.

Postprocessing

Unlike terrestrial, underwater images should always go thru some enchanting before being used in photogrammetry software. Removing the haze effect or reducing shadows can help us obtain more data from images. Setting a proper white balance for all pictures makes the final result look more realistic. The workflow in photogrammetric software is the same as in the case of terrestrial sites.

Hydroacoustic imaging

Hydroacoustic imaging is the most common method used in underwater research and large scale surveys. Many different types of devices use sound waves in the underwater environment. Almost all of them can be used in archaeological research.

The very basic echosounders used to measure the distance from the boat to the seabed. This method has a very limited application in recording archaeological structures. However, with proper software, those simple devices can be used to create medium-resolution bathymetric maps. That kind of maps can help to understand the topographical context of archaeological sites and provide an excellent base for further, more precise investigations.

Side-scan sonars give us two-dimensional images of the investigated area with visible objects protruding from the seafloor. Quality of those images enables not only the location but also preliminary interpretation of archaeological features.

Multibeam sonars are one of the most advanced hydroacoustic devices. With the use of multibeam, it is possible to create a three-dimensional model of the seabed and objects protruding from it. Quality and precision of this 3D imaging enable not only the location and preliminary interpretation of archaeological sites but also allow collecting measurements and creating necessary documentation. Standard multibeam sonar is usually attached to a boat. That kind of setup is similar to the laser scanner systems on board of planes and gives quite comparable data as well. In most cases, the resolution of the data is represented by the 10-cm and 5-cm grid. There are also multibeam sonars that work like stationary laser scanners and even live view scanners. All those devices provide dens point cloud that reflects the shape of the investigated area or feature. It is possible to use that 3D data in animations or VR applications.

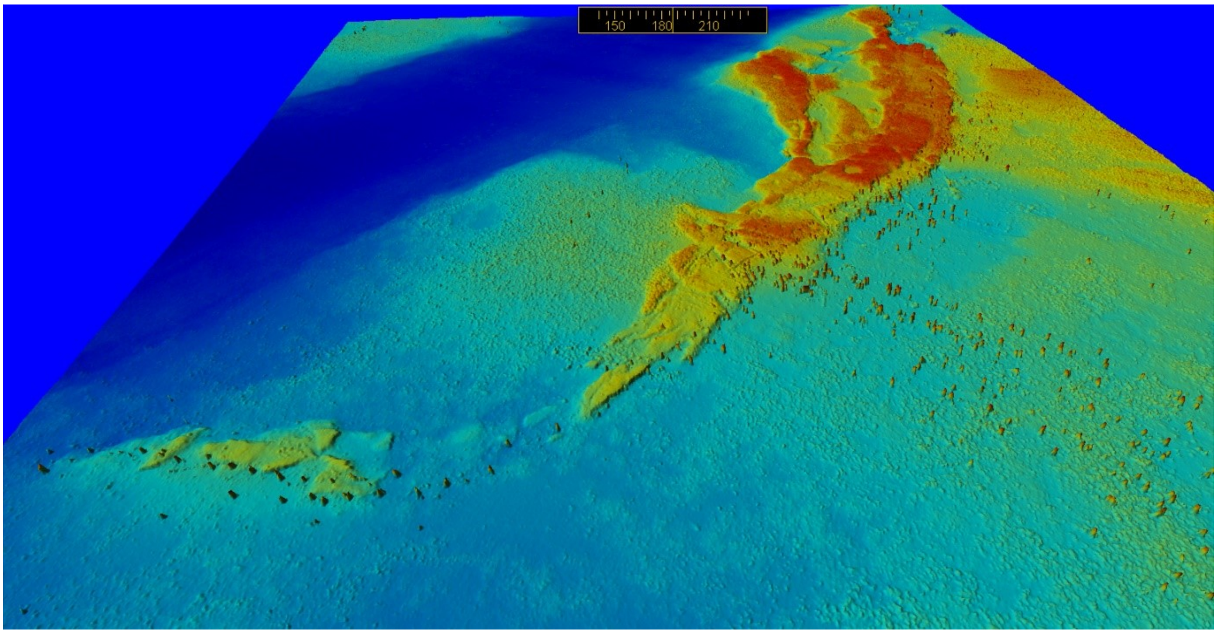

Fig 14: Topography of submerged harbour made with multibeam echosounder (J. Koszałka, UMK).

The apparent disadvantage of hydroacoustic methods is that they cannot create colour textures that reflect the authentic appearance of investigated objects. The most significant advantage is the fact that sonar devices can be successfully used in poor visibility conditions.

Seismic method

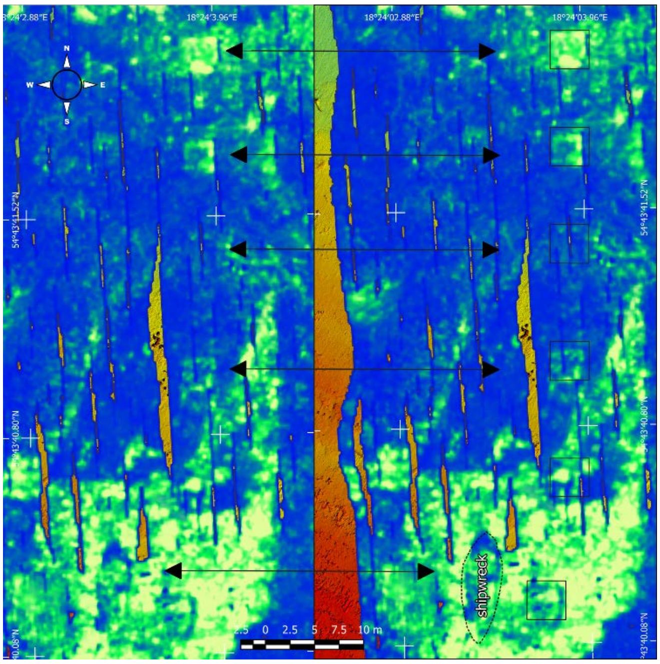

Fig 15: Fig 4. Objects in sediments visible on parametric sub-bottom profiler scan (image: M. Popek – J. Lowag, UMK)

Sub-bottom profiler uses sound waves as well; however, those waves travel through water and penetrate the sediment. The device that can track anomalies covered in sediment is a handy tool for archaeological investigations. Interpretation of data is hard for someone without experience; therefore, it is recommended to use the help of geophysicists. Profiler takes measurements only directly from beneath its sensor. To obtain a bigger picture of sediment layers in a particular area, it is necessary to create a very dense mesh of measurements. Systems with multiple sensors can make it a bit easier. Measurements from sub-bottom profiler can be displayed as profiles, 2D maps and in 3D, which makes interpretation of data much more comfortable.

Other methods

Structured light scanning and laser scanning are methods hard to use in an underwater environment. It is, however, worth mentioning that there are LIDAR systems capable of penetrating clear water on small depths.

HERITAGE RECONSTRUCTION

In the Baltic Sea shipwrecks covered with cargo are in most cases very well preserved. Thanks to that, proper in situ conducted 3D documentation can provide an excellent foundation for accurate ship reconstruction. Unfortunately, digital documentation and reconstruction of pile constructions are much more challenging. Eroded wooden logs are usually all it is left from piers and bridges. It takes much effort to figure out what kind of constructions could be based on the logs and what was their function. To 3D reconstruct archaeological sites like harbour areas, archaeologists have to use different surveying methods to collect as much data as possible. Hydroacoustic, seismic, magnetic, and other methods combined with dendrochronological sampling can provide archaeologists with a bigger, more clear picture of the submerged site (fig. 16).

Fig 16: Implementation of photogrammetric model into hydroacoustic image (UMK)

VISUALISATION

The 3D visualisations of underwater cultural heritage give the general public opportunity to visit otherwise inaccessible places. Even divers usually see only a small part of the archaeological site while visualisations based on the modern underwater survey can give the real “big picture” of the monument.

Augmented Reality methods are trendy for archaeological sites located in or near to public areas. The ability to perceive the past through mobile devices is, without any doubts, very attractive method of presenting heritage. Also, AR headsets are slowly gaining popularity and start to be used for archaeological presentation. A good example of AR usage for the presentation of results of archaeological research is Zürich Opéra-Project, where Microsoft HoloLens were used to show pile dwelling structures. Unfortunately, underwater sites are not usually so close to public areas, and their distance from shore makes that kind of presentation impossible. Of course, artefacts can be presented using AR in any place in the world; however, it is not the same as looking at them in their original location. Therefore, Virtual Reality is a more common choice when it comes to underwater heritage. Correctly made VR application can show archaeological monuments and their reconstructions, as well as take the audience to the inaccessible underwater environment. Visitors wearing VR headsets can admire cultural heritage and, simultaneously, enjoy the simulation of diving.

Fig 16: Virtual reconstruction and video animation view of medieval harbour of Puck (© UMK Torun).

Animations and online presentations based on underwater 3D documentation should be combined with reconstruction attempts (fig. 16). Reason for that is the unrecognizable appearance of most of the submerged monuments for the average viewer. Especially sonar data need some kind of explanation or context to be fully understood by the audience.

Case studies – Landscape Archaeology

The trouble with landscapes is that they are huge. Archaeology operates on a continuum of scales, ranging from the microscopic analysis of a single artefact or sample to regional or even global long-term cultural change. However, the scale is not a mere mathematical abstraction. Artefacts, structures, sites, landscapes … are not arbitrary scales of analysis, but are related to social and natural processes that form the archaeological record. The scale itself tells us something about reality. The landscape is, therefore, not merely vast, merely a unit of analysis over and above the "site", but an object of investigation in its own right.

LANDSCAPE IN ARCHAEOLOGY

Archaeological landscape, as an object of study, could be defined as the materialisation of the past in spatial terms. Landscape archaeology would then be concerned with analysing the processes of construction, function, signification, valorisation, visualisation, and preservation of that material medium through time. The specific way archaeologists approach to landscape is concerned with the material, durable aspects of the past spatial practices. The idea of landscape in archaeology has been addressed in three widely different approaches, which can be regarded as complementary to each other rather than mutually exclusive.

- First, the landscape can be seen as space, a context to understand the spatial patterning of the material record, or as a space for artefacts (finds, structures, sites). It is a common approach used in settlement pattern analyses or off-site archaeology.
- Then, a modern landscape can be seen as an artefact, a cumulative result of past human cultural practices, a research object in itself, considering that the landscapes we see today should be considered as an archaeological record as a whole. This approach addresses past aspects of archaeological and landscape heritage, and the ways the past is incorporated, used and reused in the present.
- On the other hand, the landscape can be seen as something that archaeological research aims to reconstruct, by creating images of past landscapes at different moments in the past using different methods and approaches, for example, environmental reconstruction, mapping of past features, visualisation etc. This approach is especially suitable for different kinds of archaeological visualisations as it allows us to imagine landscapes that are no more.

Landscape visualisations must and should incorporate aspects of all three concepts mentioned above. The visualised landscape, thus, shows the landscape in the past (either as distribution of sites, artefacts etc.) or the past landscape at a particular moment in the past, but also as a process of continuity and change, as a landscape history, the ways it has been modified by time, the human activities through the centuries. Visualising continuity and change can help to understand cultural the time-depth of modern landscape and lost, hidden and buried aspects of a landscape.

LANDSCAPE AS CULTURAL RESOURCE

The modern landscape is understood as heritage and cultural asset, which can be used the touristic or cultural resource. In this way, the present-day landscape is the main object of study and protection; it is focused on how the present survives in (and makes) the past. The modern landscape is, therefore, also an anchor point for visualisations. The modern landscape provides a familiar spatial context and point of reference; it is also highly quantified (there exist all kinds of data about modern landscapes) and, thus, allows spatial reference of the fragments of the past.

The main element of visualisation of the landscape are contagious areas, not just point data. They should address the landscape as a whole and not just isolated sites and where aspects of the landscape, no matter how modern, ordinary or unattractive is part of landscape character, not just "special" areas are essential; and extent of human agency and intervention, as natural and living features (e.g. lakes, woodland, hedges, land cover, peat). Visualisations should also be concerned with the degree as it is much a part of landscape character as are archaeological features.

Visualisations, thus, should provide a context for appreciating how archaeological sites fit into the historic landscape. It should focus on the time-depth, treating landscape as a matter of history rather than, or besides geography. Visualisations could make evident that everything in the landscape has historical roots, and even the most recent examples of landscape features are part of a long chain of events that stretches back across centuries or millennia.

The visualisation of the landscape should be understood as a matter of interpretation, where perceptions and opinions, ideologies, past and present, are also an essential aspect of landscape context.

VISUALISING LANDSCAPES

The fact that landscapes are vast requires the use of powerful tools to manage data and produce visualisations. One of the critical aspects of landscape studies in archaeology is the use of spatial technologies. Information technologies have gained increasing importance in data manipulation, mapping, analyses, and landscape visualisation. The increasing incorporation of spatial technologies has continued to enhance our ability to collect, store, analyse and represent archaeological data.

Remotely sensed images of the earth surface have increased in quality, availability, and potential to be integrated within a GIS environment. New technologies such as lidar create remarkably detailed models of ground topography that can be used for the detection of archaeological features and visualisation. New tools such as unmanned aerial vehicles (UAVs), accessible photogrammetry software, and 3D geoinformation technologies are resulting in high-quality three-dimensional data. Advances in GIS and remote sensing resulted in spatial databases that now regularly include thousands of individual features spaced over large study areas.

The methodological impacts of these technologies can be seen in both research, as well as archaeology heritage management. Results include not only the discovery and protection of new sites and the complete survey of known sites, but also the promotion of an ethic on non-destructive, or minimally destructive field archaeology, and incorporation of archaeological data in spatial planning.

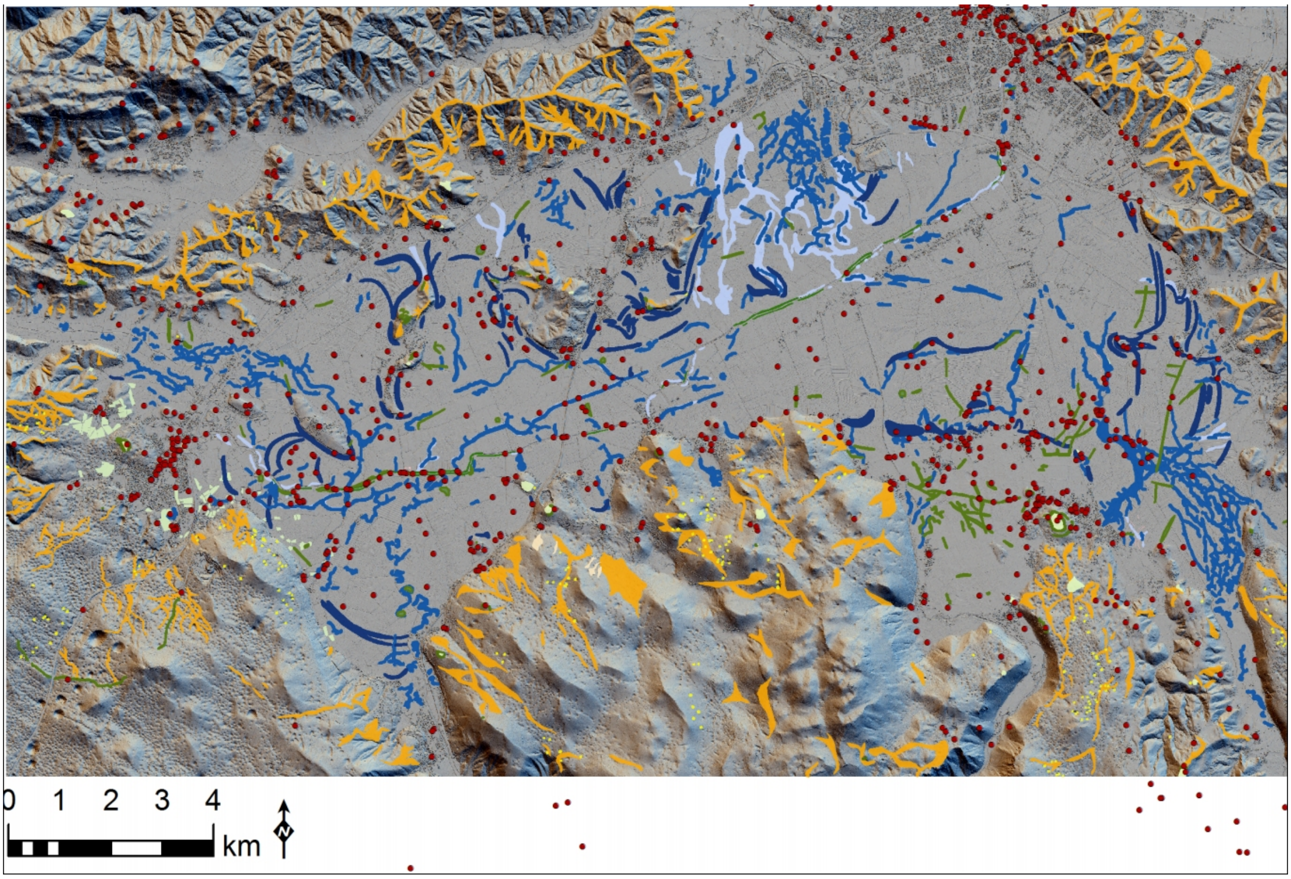

Fig 17: GIS database of Ljubljansko barje heritage (D. Mlekuž Vrhovnik, Institute for the Protection of Cultural Heritage of Slovenia).

Spatial technology

Spatial technology has had an immense impact on our ability to create, manage, analyse, and especially visualise and image data sets, and share our finds with other professionals and the public. Especially Geographic information systems (GIS) have gradually become the platform that should be used to manage large spatial sets of information. GIS allows to integrate heterogeneous data from different sources, ranging from archival information, remote sensing data, geophysics, and other fieldwork into a georeferenced database, that can be analysed and integrated with readily available data (such as topographic maps, digital elevation models, cadastral data, land use datasets, etc.).

The integration of spatial technologies within landscape studies in archaeology has brought to the fore new conceptions of archaeological data. It is especially true in the field of the so-called Big Data. This research often deals explicitly with scale and complexity in the archaeological record. The ability to collect and analyse large quantities of data enables us to shift from a more traditional site-centric settlement pattern approach to a fuller understanding of dynamic landscapes and their archaeological interpretation.

The intersection of information systems and archaeology provides new paradigms and research venues. So far, spatial technologies have been conceived as useful tools that can sometimes be applied to working processes in archaeology that are already well established. A possible direction for future developments lies in dealing with the implications of all of these in conceptual and theoretical terms, in exploring how the construction of digital landscapes is not only a way of reproducing the real world but also a new framework of reference for approaching and exploring it in different, novel ways. Here, issues of landscape visualisation are especially important.

Tools for visualzation of digital landscapes

The essential qualities of heterogeneous data require novel ways of data visualisation. Maps, traditional ways for visualising spatial data, are not best suitable for visualising the complexity of past landscapes. Their highly abstract nature and predefined conventions are less suitable for experiencing past landscapes. Immersive and mobile systems provide better opportunities to discover, assess and interpret multi-layered archaeological data, in particular, 3D data sets. There is also space for other, non-visual ways of experiencing landscapes, exploring multi-modalities of perception including haptic, sonic and olfactory stimuli.

Virtual Reality (VR) has become a mainstream term for referring to the creation and manipulation of a virtual world within a computer environment. VR has been applied to many projects relating to the virtual reconstruction or imagining of past landscapes. Some even suggested that the use of VR may be the paradigm shift within GIS studies, enabling an entire 3D landscape to be created and analysed. When visualising past landscape, virtual reality (with purely imagined or virtual landscapes) is not the only option.

Augmented Reality (AR) makes it possible to incorporate virtual elements directly into the real world. AR "allows a user to work in a real-world environment while visually receiving additional computer-generated or modelled information to support the task at hand" (Schnabel et al. 2007, 4). This involves typically putting virtual objects onto live video feed from a mobile device. It is especially useful in visualisation of computer-generated GIS data overlaid onto actual locations. The importance of AR for landscape visualisation is that it makes possible the juxtaposition of reconstructed elements of heritage on the modern, well-known landscape.

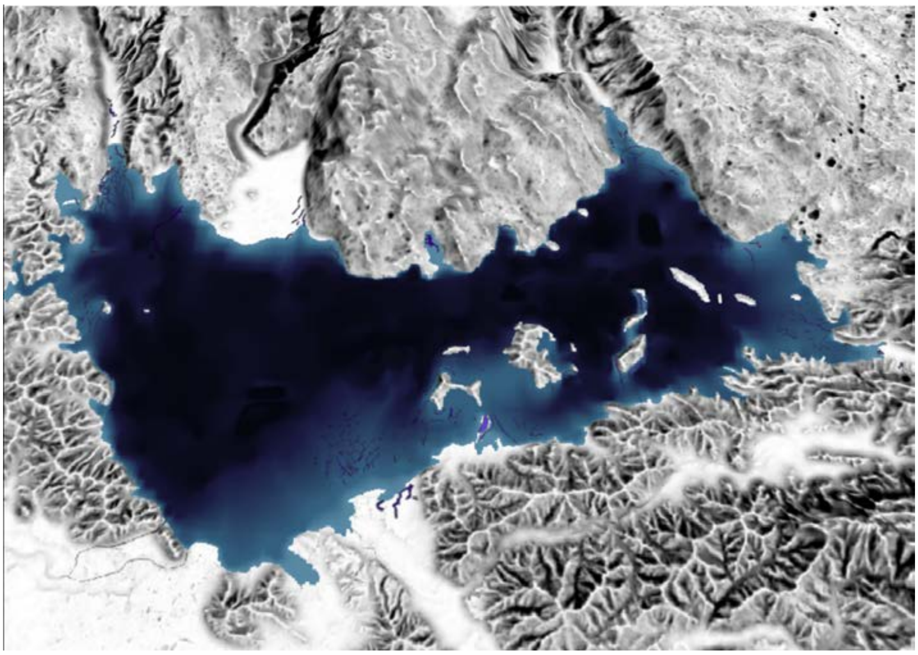

Fig 18: Reconstructed extent of a prehsitoric lake (D. Mlekuž Vrhovnik, Institute for the Protection of Cultural Heritage of Slovenia).

It has become relatively cheap and straightforward to create an immersive three-dimensional AR or VR maps with a combination of game engines, software development kits for streaming and rendering geospatial data, and affordable hardware. However, most examples of VR in archaeology capitalize on their ability to render realistic scenes of the past. Many are aimed at the heritage industry and production of imagery for public consumption. It is not the full potential of VR tools in landscape visualisation. The ability to render alternative versions of the past landscapes can be instrumental in providing new insights and raising new questions. Presentation of sophisticated models aids to discover and make intelligible data that otherwise would be impossible to grasp. However, there are visualising change. There are still open represents the change in the landscape.

LJUBLJANSKO BARJE AS A PRIME EXAMPLE

How to approach visualising past landscapes? Ljubljansko barje, one of the pilot regions within the VirtualArch projects, can be used as an example. Ljubljansko barje is a vast wetland in the centre of Slovenia. In the past, the Ljubljansko barje was a complex and dynamic mosaic of different environments, including the lake, floodplain, and wetlands. The Ljubljansko barje and its archaeological heritage should, therefore, be understood as a whole, as a result of long-term interactions of people with a specific and dynamic environment. The result is a unique archaeological heritage, with excellent preservation of organic cultural material and paleoenvironmental data. The main task of visualisation is to make this long history of interactions that created Ljubljansko barje landscape visible and tangible. In this way, the complex heritage of Ljubljansko barje becomes involved in a modern landscape.

Challenges for visualizations

This complex landscape poses several challenges for visualisation. These range from data collection and management, to selection of themes and ways of presenting the visualisations. Ljubljansko barje is one of the most intensively studied regions in Slovenia, over a century and half of research has amassed a large quantity of data. Ljubljana Barje was a focus of research of many disciplines besides archaeology (geology, hydrology, botany, geography, history). However, most of the data is fragmented and decontextualised, scattered over many publications and sources. The main challenge is compiling and integrating such a vast corpus of data to serve as a foundation for comprehensive visualisation of Ljubljansko barje landscape in the past. Data were integrated into a single model, standardised, geolocated and contextualized using GIS tools (fig. 17) and up-to-date available geospatial data (mainly lidar and aero photographs). This model served as a foundation for dedicated visualisations:

I. Visualization of landscape change

We decided to focus on the visualisation of the landscape change of the Ljubljansko barje from the end of the Pleistocene until modern times. Our attention has primarily focused on the lake dynamics, starting from the deep Late-glacial lake (fig. 18) to the periodically flooded area of the Bronze age, development of river network, and the emergence of the peat bog, with the simulation of the peat growth. Thus, the visualisation incorporates around 12.000 years and covers an area of around 50.000 sq. km. The visualisation incorporates data from historical and archival sources. The main goal is to show and demonstrate the massive landscape change and how landscape, encountered on the field, cannot be taken for granted, at least not over a long time-span. Here, the user controls the flow of time and explores the landscape change. Visualisation intends to explore dynamics and change, and not the immersive experience of being within the past landscape at a particular moment.

On the other hand, visualisation of the selected pile-dwellings from the list of UNESCO protected heritage is intended to be experienced against the landscape background. These visualisations, thus, present the newest and state-of-the-art of the current knowledge of the spatial organisation, extent and size of pile dwellings. Excavations of pile dwellings were limited to small test trenches; therefore, prior to the project, no information was available on the extent, distribution, and spatial organisation of the settlement. The geophysical survey we performed during the fieldwork enables us to visualise pile dwellings as settlements, located in a dynamic landscape, and provide the user with the information on the veracity of visualisation (fig. 19). Visualisations were intended to expand the understanding of the position and spatial structure of the pile-dwellings within a modern landscape. The problem with the pile dwellings is that they are completely invisible in a modern landscape; when visiting the area, the visitor sees only modern fields, with absolutely no indication of the heritage. It makes it extremely difficult to imagine prehistoric pile-dwelling villages. Here, we used stylised visualisation based on the infographics visual language. The primary rationale was to focus on the most important and known aspect of prehistoric settlements – the positions and sizes of individual houses and their relationships (fig. 20). The visualisation, thus, enables the user to experience the organisation and size of the village on its original location within the modern landscape.

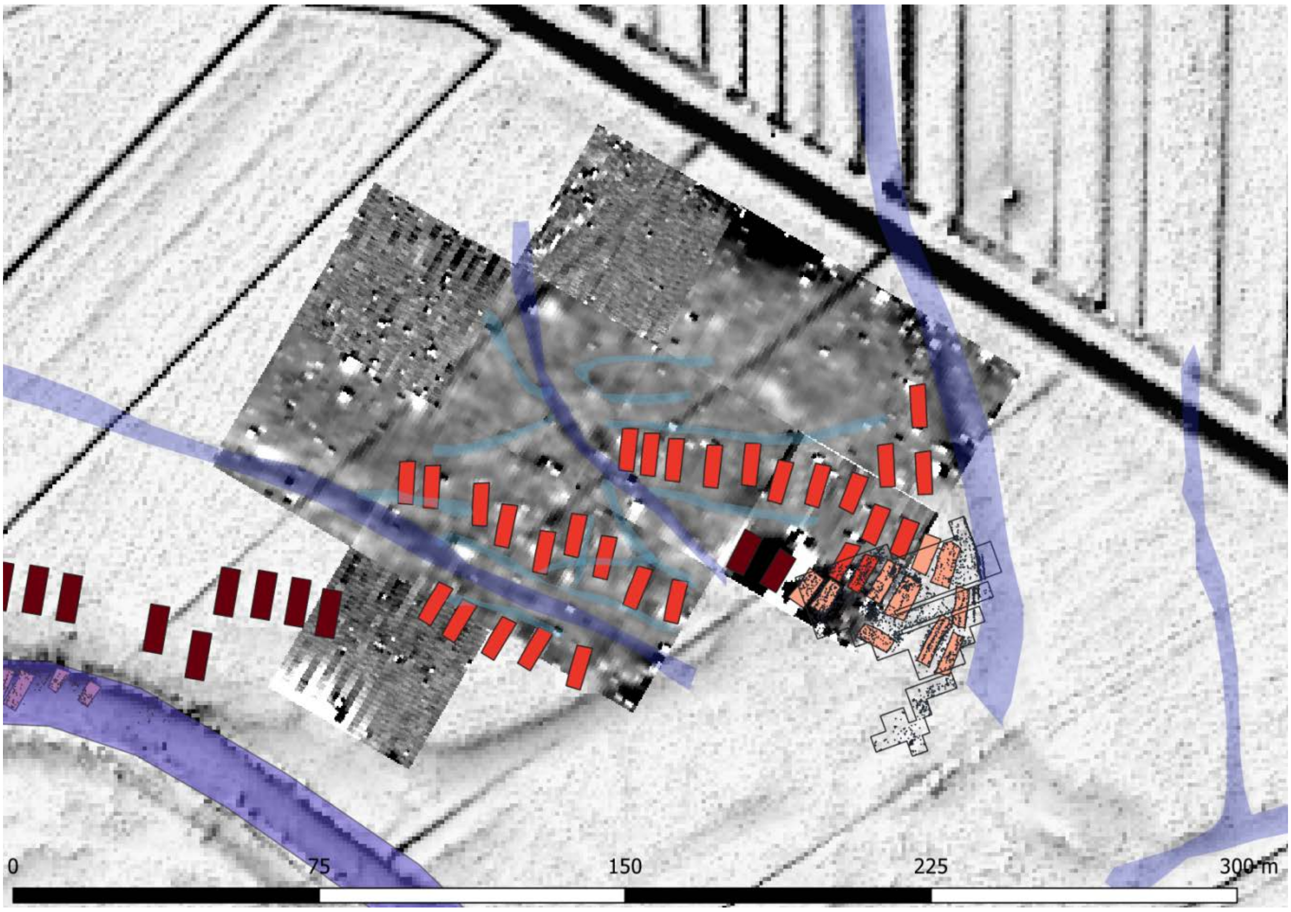

Fig 19. GIS database of Maharski prekop pile dwellings. It includes excavation data, geophisics, lidar anomalies and intrpeted location of prehistoric houses (D. Mlekuž Vrhovnik, Institute for the Protection of Cultural Heritage of Slovenia).

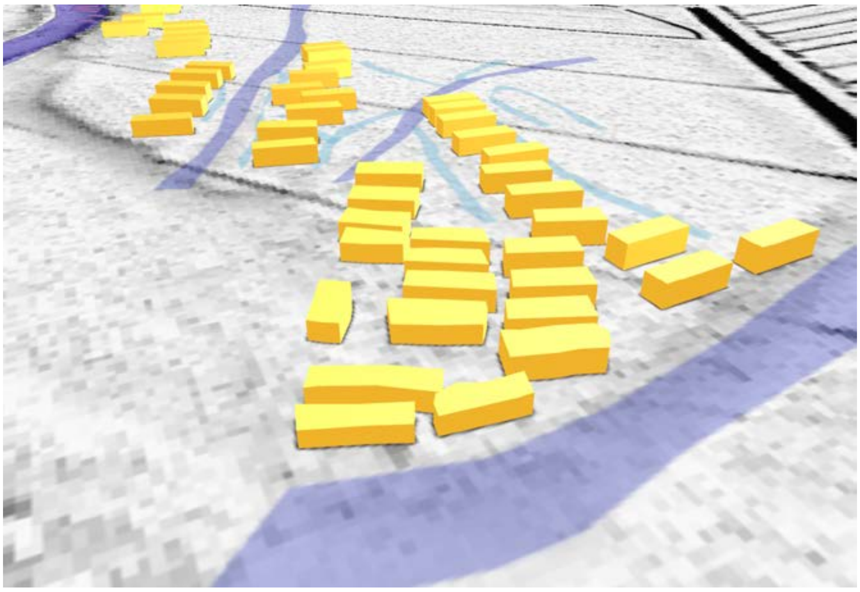

Fig 20: Reconstructed extent of Maharski prekop pile dwelling (D. Mlekuž Vrhovnik, Institute for the Protection of Cultural Heritage of Slovenia).

II. Experience of landscape change

Visualisations form part of an AR application that affords a very plastic and tangible exploration of invisible heritage within the modern landscape, in its original position. Field tests with potential users and stakeholders were very encouraging, as they described the experience as an “eye-opening”, allowing for the first tangible and visible experience of prehistoric settlement, hidden beneath the ground in an original location.

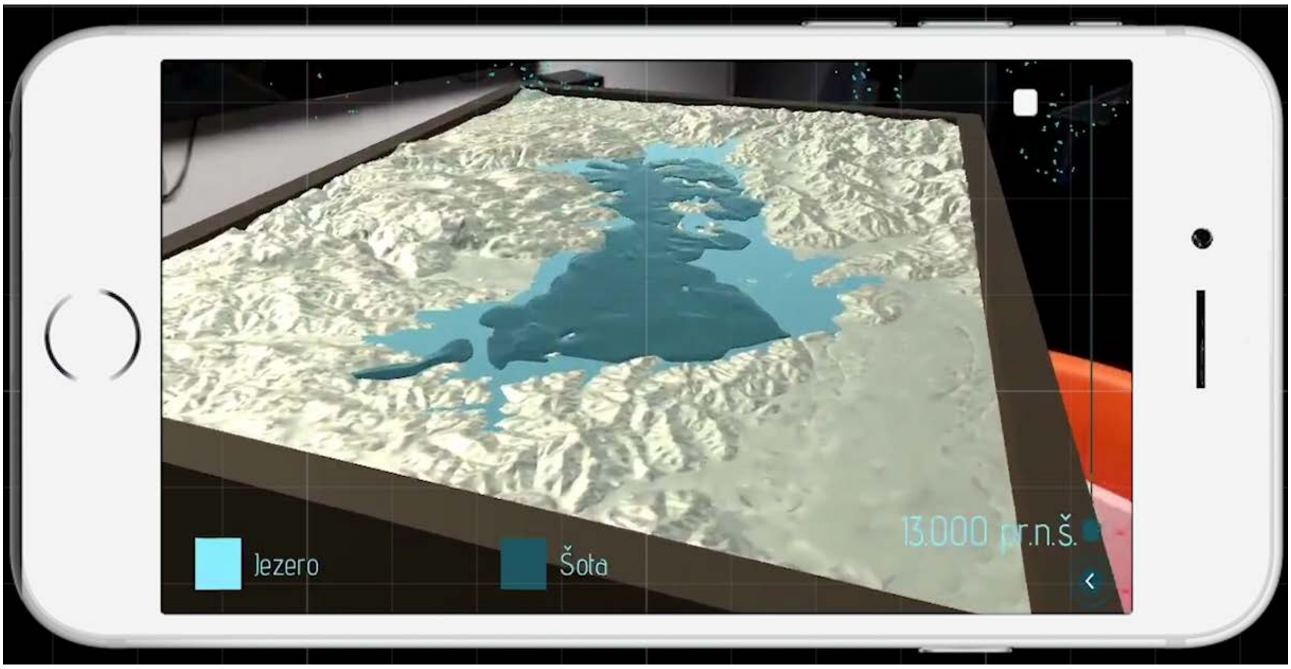

Fig 21: AR application that shows the amountg of Ljubljansko barje landscape change (D. Mlekuž Vrhovnik, Institute for the Protection of Cultural Heritage of Slovenia).

The main issue when designing individual visualisations is how to disseminate them to the public, how they are intended to be experienced. The visualisations themselves are not enough; they have to be part of a more comprehensive narrative and message. Thus, the way users and stakeholders experience and use landscape visualisations, videos and interactive maps are essential and directly addresses the aims of visualisation – to make the invisible heritage tangible. We want the users to be able to explore the invisible heritage by themselves. Thus, the point is to have a direct, unmediated experience of the landscape change and pile-dwelling sites.

When designing the visualisations, we wanted even more "open-world" approach, where the users would be completely free to roam and explore Ljubljansko barje, for example, how deep the lake was in their location in the arbitrary moment in the past, or how did the peat bog obscure the horizon at their location etc. It has turned out that due to the technical limitations – geolocation precision, orientation, AR core capabilities, this cannot be done for the whole area of Ljubljansko barje (which covers around 50.000 sq. km) – we limited the location-based AR to selected areas on Ljubljansko barje.

Fig 22: AR application exploration of prehistoric pile dwelling in their landscape context (D. Mlekuž Vrhovnik, Institute for the Protection of Cultural Heritage of Slovenia).

Such "areas of interest" with particular information allow users to see location-specific views and information, for example, how was the pile-dwelling visible on the surface, where it was located within the modern landscape, how were settlements organised etc. Such range of information also means that visualisations should be anchored in a modern landscape and exploit modern infrastructure and landmarks, such as roads, access points, information boards.

CONCLUSION

The landscape is a concept with an open meaning; it might be related to natural properties or the personal and symbolic experience; it might show patterns of stability or path of change and transformation. Landscapes may be explored in totally different ways and a variety of scales. Nevertheless, it is a crucial issue - a concern with the human experience of the surrounding world.

To understand what it was like to live in the past, you have to experience it for yourself. Although the past is inaccessible, visualisation methods can help us to approach it. The main aim of landscape visualisation is to make past landscapes more tangible and visible. It includes visualisations of the extent of the heritage still buried beneath the earth, the scope of landscape change, to what extent the landscape has been modified in the past, the fact that the whole landscape is an artefact corroborating human interventions and every intervention could have a long-lasting effect on heritage and landscape itself.

Forgotten, lost, concealed, and erased traces in the landscape come alive by using visualisations; forgotten traces once again become part of the living landscape. In this way, they intertwine with the interests, work and life of stakeholders. Our scientific practices also have direct implications, in the sense that we represent hidden archaeological heritage in a democratic process of negotiating the future.

Literature

Apollonio, F. I., 2016. Classification Schemes for Visualization of Uncertainty in Digital Hypothetical Reconstruction, in 3D Research Challenges in Cultural Heritage II: How to Manage Data and Knowledge Related to Interpretative Digital 3D Reconstructions of Cultural Heritage, eds. S. Münster, M. Pfarr-Harfst, P. Kuroczynski and M. Ioannides, 173-198. Cham: Springer International Publishing.

Arnold, C. J., J. W. Huggett, P. Reilly, and C. Springham. 1989. Mathrafal: A Case Study in the Application of Computer Graphics. In Computer Applications and Quantitative Methods in Archaeology 1989. CAA89, ed. S. Rahtz, 147-156. (BAR International Series 548). Oxford: Archaeopress.

Barceló, J. A. 2001. Virtual reality for archaeological explanation. Beyond "picturesque" reconstruction. Archeologia e Calcolatori 12: 221-244.

Biek, L. 1985. LERNIE XIV: Comparology and Stereovideo. In Computer Applications in Archaeology 185: Proceedings of the Conference on Quantitative Methods, Institute of Archaeology, London, March 29 – 30, ed. E. Webb, 1-35. (Online: https://proceedings.caaconference.org/paper/01_biek_caa_1985/)

Brusaporci, S. 2017. The Importance of Being Honest: Issues of Transparency in Digital Visualization of Architectural Heritage. In Handbook of Research on Emerging Technologies for Architectural and Archaeological Heritage, ed. A. Ippolito, 66-92. Hershey: IGI Global.

Carmigniani, J., and B. Fuhrt. 2011. Augmented Reality: An Overview. In Handbook of Augmented Reality, ed. B. Fuhrt, 3 – 46. New York: Springer

Eiteljorg, H. 2000. The Compelling Computer Image – a double-edged sword. Internet archaeology 8. (online: http://intarch.ac.uk/journal/issue8/eiteljorg_index.html)

Florjanowicz, P. 2016: From Valletta to Faro with a stopover in Brussels. International legal and policy background for archaeology or simply the understanding of heritage at the European level. In: Paulina Florjanowicz (Ed.) When Valletta meets Faro. The reality of European archaeology in the 21st century, EAC Occasional Paper No. 11, 25-32.

Forte, M., A. Siliotti (eds). 1997. Virtual Archaeology: Re-creating Ancient Worlds. New York: Harry N. Abrams.

Golvin, J.-C. 2012. Drawing Reconstruction Images of Ancient Sites. In Picturing the Past. Imaging and Imagining the Ancient Middle East, eds. J. Green, E. Teeter, and J. A. Larson, 77-82. Chicago: The Oriental Institute of the University of Chicago.

Isenberg, T., P. Neumann, S. Carpendale, M. C. Sousa, and J. A. Jorge. 2006. Non-Photorealistic Rendering in Context: An Observational Study. In Proceedings of the 4th International Symposium on Non-Photorealistic Animation and Rendering 2006, Annecy, France, June 5-7, 2006, eds. D. DeCarlo, and L. Markosian, 115-126. New York: AMC Press.

Kantner, J. 2000. Realism vs. Reality: Creating Virtual Reconstructions of Prehistoric Architecture. In Virtual Reality in Archaeology, eds. J. A. Barcelo, M. Forte, and D. H. Sanders, 47-52. BAR International Series 843. Oxford: Archaeopress.

Mandal, S. 2013. Brief Introduction of Virtual Reality & its Challenges. International Journal of Scientific & Engineering Research 4 (4): 304 – 309.

Mccormick, B. H., T. A. Defanti, and M. D. Brown. 1987. Visualization in Scientific Computing. Computer Graphics 21 (6): 1-14

McCurdy, L. 2012. Virtual Architectural Reconstruction and Visual Anthropology. Anthropologies 10.

Miller, P., and J. Richards. 1995. The Good, the Bad, and the Downright Misleading: Archaeological Adoption of Computer Visualisation. In CAA94. Computer Applications and Quantitative Methods in Archaeology 1994, eds. J. Huggett, and N. Ryan, 19-22. BAR International Series 600. Oxford: Tempus Reparatum.

Olivier, A. 2016: Challenging attitudes – delivering public benefit. In: Paulina Florjanowicz (Ed.) When Valletta meets Faro. The reality of European archaeology in the 21st century, EAC Occasional Paper No. 11, 13-23.

Reilly, P. 1991. Towards a Virtual Archaeology. In CAA90. Computer Applications and Quantitative Methods in Archaeology 1990, eds. S. Rahtz, and K. Lockyear, 132-139. BAR International Series 565. Oxford: Tempus Reparatum.

Reilly, P. 1992. Three-dimensional modelling and primary archaeological data. In Archaeology and the information age: a global perspective, eds. P. Reilly, and S. Rahtz, 92-107. London: Routledge.

Reilly, P., and S. Rahtz (eds). 1992. Archaeology and the Information Age: A Global Perspective. London and New York: Routledge.

Samara, T. 2014. Grafický design: Základní pravidla a způsoby jeho porušování. Praha: Slovart.

Sanders, D. 2014. More than Pretty Pictures of the Past: An American Perspective on Virtual Heritage. In Paradata and Transparency in Virtual Heritage, eds. A. Bentkowski-Kafel, H. Denard, and D. Baker, 37-56. Farnham: Ashgate.

Schäfer, U. U. 2018. Uncertainty Visualization and Digital 3D Modeling in Archaeology. A Brief Introduction. International Journal for Digital Art History 3: 87 – 105.

Schiffer, M. B. 1972. Archaeological context and systemic context. American Antiquity 37:156-165.

Schnabel, M. A., X. Wang, H. Seichter, and Th. Kvan. 2007. From Virtuality to Reality and Back. Conference paper: International Association of Societies of Design Research (IASDR), Hong Kong.

Sifniotis, M., B. Jackson, M. White, K. Mania, and P. Watten. 2006. Visualising uncertainty in archaeological reconstructions: a possibilistic approach. In Proceedings SIGGRAPH '06 ACM SIGGRAPH 2006 Sketches, July 30 – August 03, Boston, eds. J. Finnegan and H. Pfister, 1-1. New York: ACM.

Sims, D. 1997. Archaeological Models: Pretty Pictures or Research Tools?. IEEE Computer Graphics 17 (1): 13-15.

Spaulding, A.C. 1960. The dimensions of archaeology. In Essays in the Science of Culture: In Honor of Leslie A. White, ed. J.E. Dole, and R.L. Carneiro, 437- 456. New York: Thomas Y. Crowell.

Strothotte, T., M. Masuch, and T. Isenberg. 1999. Visualizing Knowledge about Virtual Reconstructions of Ancient Architecture. In Proceedings Computer Graphics International. The Computer Graphics Society, IEEE Computer Society, 7-11 June, 1999, Los Alamitos, ed. T. Lewis, 36-43. Los Alamitos: IEEE Computer Society Press.

Wheatley, D. 2000. Spatial Technology and Archaeological Theory Revisited. In Computer Applications and Quantitative Methods in Archaeology, eds. K. Lockyear, T. Sly, and V. Mihailescu-Birlitsa, 123-131. (BAR International Series 2000). Oxford: Archaeopress.

Willems, W. J. H. 2014: Malta and its consequences: a mixed blessing. In: Victoria M. van der Haas and Peter A.C. Schut (Eds.) The Valletta Convention Twenty Years After - Benefits, Problems, Challenges. EAC Occasional Paper No. 9, 151-156.

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With a budget of 246 million Euro from the European Regional Development Fund (ERDF), Central Europe support partnerships made up of public and private institutions from nine countries: Austria, Croatia, Czech Republic, Germany, Hungary, Italy, Poland, Slovakia and Slovenia.
In projects people from all kind of institutions work together to tackle shared challenges in their cities and regions - in the fields of innovation, CO_2 reduction, natural and cultural resources, and sustainable transport. More concretely, our projects build regional capacities by involving and coordinating relevant players from all governance levels. Within the four priority axes, they realize outputs with a focus on policy-learning, pilot actions and pilot investments.

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