Interreg
Danube Transnational Programme
Danube's Archaeological eLandscapes

Standards for DIGITAL RECONSTRUCTION AND VISUALISATIONS OF ARCHAEOLOGICAL HERITAGE

Standards for digital reconstruction and visualisations of archaeological heritage

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DIGITAL RECONSTRUCTION AND VISUALISATIONS OF ARCHAEOLOGICAL HERITAGE

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EUROPEAN UNION
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TABLE OF CONTENTS

SUMMARY

In the course of the Virtual Archaeological Landscapes of the Danube Region project (Danube's Archaeological eLandscapes), co-financed by the Danube Transnational programme, partners from 10 countries focused on making state-of-the-art digital visualisations of archaeological heritage, with an emphasis on archaeological landscapes. In October 2021 the partnership adopted a strategy named Sustainable touristic value from digitization of archaeological heritage: *Digital approaches to the promotion of archaeological landscapes in the Danube region*. The strategy proposes a special workflow for making digital visualisations, one which takes into account archaeological, technological and social questions that need to be tackled during the process of making such visualisations.

In September 2021 an international working group for the development of standards was formed by experts from the partnership. Tasks of the working group included evaluations of the four Industry Forums which were organised within the scope of the project by project partners from Hungary (November 2021), Slovenia (April 2022), Romania (June 2022) and Slovakia (October 2022). The forums focused on presentations of various possibilities for the digital presentation of cultural (archaeological) heritage. The evaluations, together with the lessons learned by the partners when applying the workflow from the strategies in their visualisations, formed the basis for these standards.

The standards consist of four main parts. First is the presentation of the most relevant international strategies, charters and other relevant documents that deal with various aspects of digitally presenting cultural (and thus archaeological) heritage. The second and third chapters are strongly connected to the workflow proposed in the above strategies. With the help of the Industry Forum evaluations and the partners' responses to the workflow, the second chapter presents guidelines for using the workflow.In the third chapter, practical examples of the work through the workflow stages are presented by the project partners involved in making the visualisations. In the final part of the document, the practical examples from the third chapter are analysed and recommendations for each stage are put forward. An additional component of the final chapter is an analysis of time spent in making the visualisations by our Croatian partners.

Together with the strategies, these standards form a set of two documents which present, promote and evaluate the workflow for the creation of digital visualisations of archaeological heritage, as seen from the partnership of the Danube's Archaeological eLandscape project.

FRAMEWORK AND GUIDELINES

1

Marta Rakvin, *Archaeological Museum in Zagreb*

The galloping technological advance, which we have been witnessing in recent years, has led to the occurrence of many new ways to research, preserve, document, interpret and present various elements of archaeological heritage using computer-based visualisations. Simultaneously, this led to the great expansion of interpretive activities at many archaeological cultural heritage sites. On the one hand, they have shown immense potential for computer-based visualisations of archaeological heritage, but on the other hand, the archaeological community has been faced with a number of challenges, questions and inconsistencies regarding their use. In order to achieve a clear rationale, standardised terminology, and accepted professional principles for interpretation and presentation of archaeological heritage became apparent and necessary. The core of the problem can be summarised in three following questions:

1. What are the accepted and acceptable goals for the interpretation and presentation of archaeological heritage sites?
2. What principles should help determine which technical means and methods are appropriate in particular archaeological contexts?
3. What general ethical and professional considerations should help shape interpretation and presentation in light of its wide variety of specific forms and techniques?

With regard to these three fundamental questions, there are already international documents that need to be consulted. The most important ones are presented in the following:

CHARTER ON THE INTERPRETATION AND PRESENTATION OF CULTURAL HERITAGE SITES (ICOMOS, Québec, 2008)

As digital reconstructions and visualisations of archaeological sites are a form of presentation of cultural heritage in general, the ICOMOS's Charter on the interpretation and presentation of cultural heritage sites is the first legal source to be consulted when dealing with this topic. The Charter reflects and builds on the principles of the International Charter For The Conservation And Restoration Of Monuments And Sites (the

Venice Charter) and it provides the basic principles of interpretation and presentation of cultural heritage. The principles are regarded as essential components of heritage conservation efforts and as a means of enhancing public appreciation and understanding of cultural heritage sites, by also emphasising the role of public communication and education in heritage preservation.

Principle 1: Access and Understanding

Interpretation and presentation programmes should facilitate physical and intellectual access by the public to cultural heritage sites.

Principle 2: Information Sources

Interpretation and presentation should be based on evidence gathered through accepted scientific and scholarly methods as well as from living cultural traditions.

Principle 3: Attention to Setting and Context Principle

The Interpretation and Presentation of cultural heritage sites should relate to their wider social, cultural, historical, and natural contexts and settings.

Principle 4: Preservation of Authenticity

The Interpretation and presentation of cultural heritage sites must respect the basic tenets of authenticity in the spirit of the Nara Document (1994).

Principle 5: Planning for Sustainability

The interpretation plan for a cultural heritage site must be sensitive to its natural and cultural environment, with social, financial, and environmental sustainability among its central goals.

Principle 6: Concern for Inclusiveness

The Interpretation and Presentation of cultural heritage sites must be the result of meaningful collaboration between heritage professionals, host and associated communities, and other stakeholders.

Principle 7: Importance of Research, Training, and Evaluation

Continuing research, training, and evaluation are essential components of the interpretation of a cultural heritage site.

Following from these seven principles, the objectives of this Charter are to:

- Facilitate understanding and appreciation of cultural heritage sites and foster public awareness and engagement in the need for their protection and conservation.
- Communicate the meaning of cultural heritage sites to a range

of audiences through careful, documented recognition of their significance, through accepted scientific and scholarly methods as well as from living cultural traditions.

- Safeguard the tangible and intangible values of cultural heritage sites in their natural and cultural settings and social contexts.
- Respect the authenticity of cultural heritage sites, by communicating the significance of their historic fabric and cultural values and protecting them from the adverse impact of intrusive interpretive infrastructure, visitor pressure, inaccurate or inappropriate interpretation.
- Contribute to the sustainable conservation of cultural heritage sites, through promoting public understanding of, and participation in, ongoing conservation efforts, ensuring long-term maintenance of the interpretive infrastructure and regular review of its interpretive contents.
- Encourage inclusiveness in the interpretation of cultural heritage sites, by facilitating the involvement of stakeholders and associated communities in the development and implementation of interpretive programmes.

THE LONDON CHARTER FOR THE COMPUTER-BASED VISUALISATION OF CULTURAL HERITAGE

Narrowing the topic of cultural heritage interpretation and presentation into the realm of computer-based technologies, in 2006 the *The London Charter for the Computer-based Visualisation of Cultural Heritage introduced*. It was updated in 2009. The Charter is the most advanced document produced on the subject so far as it brought together results from various expert groups[1] in an all-encompassing set of recommendations for digital interpretations of cultural heritage. The Charter has been widely accepted, translated into nine languages, and has won formal endorsement from national and international bodies. The Charter forms the basis of an EU MINERVA workgroup on standards for the use of 3D technologies in capturing and representing cultural heritage, as well as of *Dissemination and Standards of the EU EPOCH Network of Excellence*. *The London Charter* has had considerable success in acting as a catalyst for establishing international consensus on the principles that should inform best practice in heritage visualisation across disciplines. It is now widely recognised as the de facto benchmark to which heritage visualisation processes and outputs should be held accountable (Denard 2012: 57)

Its main aim was to establish a set of guidelines and recommendations as a means of ensuring the methodological rigour of computer-based visualisations, of researching and communicating cultural heritage, as well as the means of achieving widespread recognition for this method (Denard 2012: 57). At the same time, such principles must reflect the distinctive properties of computer-based visualisation technologies and methods.[2] For a heritage visualisation to match the rigour of

[1] Spanish Society of Virtual Archaeology (SEAV, 2008);International Forum of Virtual Archaeology (2008); Virtual Archaeology Special Interest Group (VASIG, 2001); Cultural Virtual Reality Organisation (CVRO, 2000); Virtual Archaeology International Network (2011).

[2] The London Charter: Preamble

conventional research, the efforts involved in its production must be visible (transparent). That is why, at the heart of *The London Charter* is the principle that heritage visualisation: *'should accurately convey to users the status of the knowledge that they represent, such as distinctions between evidence and hypothesis, and between different levels of probability.*[3]

Principles of the London Charter

Principle 1: Implementation

The principles of the *London Charter* are valid wherever computer-based visualisation is applied to the research or dissemination of cultural heritage.

Principle 2: Aims and Methods

A computer-based visualisation method should normally be used only when it is the most appropriate available method for that purpose.

Principle 3: Research Sources

In order to ensure the intellectual integrity of computer-based visualisation methods and outcomes, relevant research sources should be identified and evaluated in a structured and documented way.

Principle 4: Documentation

Sufficient information should be documented and disseminated to allow computer-based visualisation methods and outcomes to be understood and evaluated in relation to the contexts and purposes for which they are deployed.

Principle 5: Sustainability

Strategies should be planned and implemented to ensure the long-term sustainability of cultural heritage-related computer-based visualisation outcomes and documentation, in order to avoid loss of this growing part of human intellectual, social, economic and cultural heritage.

Principle 6: Access

The creation and dissemination of computer-based visualisation should be planned in such a way as to ensure that maximum possible benefits are achieved for the study, understanding, interpretation, preservation and management of cultural heritage.

[3] The London Charter: Preamble

THE PRINCIPLES OF SEVILLE - INTERNATIONAL PRINCIPLES OF VIRTUAL ARCHAEOLOGY

Written at an abstract level and purposely avoiding highly-specific technical recommendations, the *London Charter* serves as a base document for all fields dealing in cultural heritage when venturing into new digital interpretations and presentations. As cultural heritage encompasses a large number of very different fields, in its 1st principle the *London Charter* recommends "Each community of practice, whether academic, educational, curatorial or commercial, should develop London Charter Implementation Guidelines that cohere with its own aims, objectives and methods". Following this logic and pertaining to the field of archaeology the *The Principles of Seville - International Principles of Virtual Archaeology* were developed. In 2017 the document was ratified by the 19th ICOMOS General Assembly in New Delhi and therefore given recognition by the expert community.

Since the Seville principles adopted the theoretical framework of the *London Charter*, they further elaborate, specify and adapt its principles to the field of archaeology by abiding to the following objectives:

- Generate easily understandable and applicable criteria for the whole community of experts, including computer experts, archaeologists, architects, engineers, general managers or specialists in the field.
- Establish guidelines aimed at giving the public a greater understanding and better appreciation of the ongoing work of archaeology.
- Establish principles and criteria for measuring the quality of projects carried out in the field of virtual archaeology.
- Promote the responsible use of new technologies for the comprehensive management of archaeological heritage.
- Help improve current archaeological heritage research, conservation and dissemination processes using new technologies.
- Open new doors for the application of digital methods and techniques in archaeological research, conservation and dissemination.
- Raise the awareness of the international scientific community of the prevailing need to make concerted efforts worldwide in the growing field of virtual archaeology.

The principles aim to increase the range of applicability of the *London Charter* in order to improve its implementation in the field of archaeological heritage, simplifying and organising its bases sequentially, while at the same time offering new recommendations taking into account the specific nature of archaeological heritage in relation to cultural heritage.

The principles of Seville are:

Principle 1: Interdisciplinarity

Any project involving the use of new technologies, linked to computer-based visualisation in the field of archaeological heritage, whether for research, conservation or dissemination must be supported by a team of professionals from different branches of knowledge.

Principle 2: Purpose

Prior to the development of any computer-based visualisation, the ultimate purpose or goal of our work must always be absolutely clear.

Principle 3: Complementarity

The application of computer-based visualisation for the comprehensive management of archaeological heritage must be treated as a complementary, and not alternative, tool to other more traditional but equally effective management instruments.

Principle 4: Authenticity

Computer-based visualisation normally reconstruct or recreate historical buildings and environments as we believe them to have been in the past. For that reason, it should always be possible to distinguish what is real, genuine or authentic from what is not.

Principle 5: Historical rigour

To achieve optimum levels of historical rigour and veracity, any form of computer-based visualisation of the past must be supported by solid research and historical and archaeological documentation.

Principle 6: Efficiency

The concept of efficiency applied to the field of virtual archaeology depends inexorably on achieving appropriate economic and technological sustainability. Using fewer resources to achieve increasingly more and better results is the key to efficiency.

Principle 7: Scientific transparency

visualisation must be essentially transparent, i.e. testable by other researchers or professionals, since the validity, and therefore the scope, of the conclusions produced by such visualisation will depend largely on the ability of others to confirm or refute the results obtained.

Principle 8: Training and evaluation

Virtual archaeology is a scientific discipline related to the comprehensive management of archaeological heritage that has its own specific language and techniques. Like any other academic discipline, it requires specific training and evaluation programmes.

LIST OF OTHER INTERNATIONAL DOCUMENTS THAT CONCERN ALL THE PROPOSED STAGES OF DEVELOPING THE VISUALISATIONS OF ARCHAEOLOGICAL HERITAGE

Apart from these three basic charters, there are also a number of other documents, which are listed in the following:

CONVENTIONS:

- European Cultural Convention (1954)
- Convention for the Protection of Cultural Property in the Event of Armed Conflict (1954)
- European Convention on the Protection of Archaeological Heritage (1969)
- Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property (1970)
- UNESCO Convention concerning the Protection of the World Cultural and Natural Heritage (1972)
- European Convention for the Protection of the Architectural Heritage of Europe (1985)
- ICOMOS Charter for the Protection and Management of the Archaeological Heritage (1990)
- European Convention on the Protection of the Archaeological Heritage (revised) – Valletta Convention (1992)
- International Cultural Tourism Charter – Managing Tourism at Places of Heritage Significance (1999)
- UNWTO Global Code of Ethics for Tourism (1999)
- European Landscape Convention – Florence Convention (2000)
- Convention on the Protection of the Underwater Cultural Heritage (2001)
- The Budapest Declaration on World Heritage (WHC, 2002)
- Convention for the Safeguarding of the Intangible Cultural Heritage (2003)
- Convention on the Protection and Promotion of the Diversity of Cultural Expressions (2005)
- Council of Europe Framework Convention on the Value of Cultural Heritage for Society – Faro Convention (2005)
- Europe Framework Convention on the Value of Cultural Heritage for Society (2005)
- Fifth “C” (WHC, 2007)
- UNWTO Framework Convention on Tourism Ethics (2017)
- The Faro Convention Action Plan Handbook (2018-2019)

CHARTERS:

- ICOMOS Charter on the Interpretation and Presentation of Cultural Heritage Sites (2008)
- The London Charter for the Computer-based Visualisation of Cultural Heritage

GUIDELINES:

- Europae Archaeologiae Consilium (EAC) Guidelines (2014-2015)
- Salalah Guidelines for the Management of Public Archaeological Sites (2017)
- Operational Guidelines for the implementation of World Heritage Convention (1976-2019)
- Expert Group on a common European Data Space for Cultural Heritage
- PREFORMA
- Basic principles and tips for 3D digitisation of tangible cultural heritage for cultural heritage professionals and institutions and other custodians of cultural heritage
- 3D Digitisation of Icons of European Architectural and Archaeological Heritage
- IANUS Forschungsdatenzentrum Empfehlungen
- ADS 3D Models in Archaeology: A Guide to Good Practice

DECLARATIONS:

- Declaration of Namur (2015)

STRATEGIES:

- European Union Strategy for Danube Region and Action Plan: Culture and Tourism (2016)
- The European Heritage Strategy for the 21st Century (2017)
- Interreg CE Virtualarch Transnational Strategy
- Sustainable touristic value from digitization of archaeological heritage. Digital approaches to the promotion of archaeological landscapes in the Danube region. (2021)

RECOMMENDATIONS:

- COMMISSION RECOMMENDATION of 27 October 2011 on the digitisation and online accessibility of cultural material and digital preservation
- VMS, Digitale Museumspraxis - Eine ganzheitliche Herangehensweise
- Deutscher Museumsbund - Empfehlungen zur Vergabe von Aufträgen an Gestalterbüros

GUIDELINES FOR USING AND DOCUMENTING VARIOUS TECHNICAL RESEARCH & VISUALISATION METHODS

2

Nika Lužnik, *University of Vienna and*
Nejc Dolinar, *Institute for the protection of cultural heritage of Slovenia*

In this chapter, we present some practical guidelines for the completion of the nine stages of the workflow for creating digital visualisations of archaeological heritage. The workflow was proposed by the partnership of the Danube's Archaeological eLandscapes project in a strategy named Sustainable touristic value from digitization of archaeological heritage: Digital approaches to the promotion of archaeological landscapes in the Danube region, adopted in October 2021.

Several stages comprise each cultural heritage project. In projects, which include computer-aided visualisation, these are the following: project planning, data acquisition, first interpretation, 3D model creation, communication strategy, II. Interpretation, 3D Model Adjustment, dissemination, and documentation. The following chapters will help readers better understand the processes of each stage.[4]

1) Project Planning

Plan from the beginning of the project whether the research methods and final presentation will include virtual 3D modelling! Supporting research and documentation methods and techniques can be, for example, Structure from Motion - Multi-View Stereo (SfM-MVS) approaches, LiDAR or terrestrial scanning or 3D processed Ground Penetrating Radar (GPR) surveys. Later through virtual 3D modelling produced objects can be raw 3D models, images, video, augmented reality (AR) or (immersive) virtual reality (VR) applications. Additionally, don't forget to include the right experts in the project team as soon as possible, such as a 3D artist and experts knowledgeable in cultural heritage and 3D modelling.

2) Data Acquisition

Collect, document, and present the research data in 3D - e.g., 3D scans, 3D models based on the SFM-MVS approach, and GPR data presented in 3D! Additionally, if possible, 3D artists can visit the cultural heritage site in person to gain an impression of the environment and ambience.

[4] Project stages and their short descriptions are based on Lužnik-Jancsary, N. (2022) *Information and Communication Potential of Computer-Aided Visualisation of Archaeological Objects (PhD Dissertation),* University of Ljubljana.

Several of the mentioned techniques result in big data sets. It is important to ensure sustainability of all collected data. Large data sets, e.g. point clouds, should be reduced before being handed over to 3D artists for easier management.

On the other hand, legacy data of old research should be digitised for further processing.

3) First Interpretation

At the stage of the first interpretation, the only difference to traditional archaeological interpretation is that more attention is paid to the interpretation of 3D aspects. For example, when interpreting architectural remains, one should consider the whole structure, like walls, doors, windows, floors, and roof construction, rather than focusing on the floor plan only.

4) 3D Model Creation

3D modelling of cultural heritage sites usually focuses on terrain, architecture and artefacts. Most of the time, very detailed modelling is not needed. However, it needs to be accurate. For the final visualisation, the combination of all the data on terrain, architecture, small objects, vegetation, fauna, and people needs to be comprehensively combined in the environment. Understandably, the view of all interpreted objects reconstructed in the virtual setting can affect the original interpretation, as the virtual environment can provide new insights into understanding the source data.

5) Communication Plan

When planning which visualisation products to make, a communication plan has to be established. This means you have to decide where and how the computer-aided visualisation will be shown. For example, if the plan is to present virtual visualisation at a workshop, accepted communication formats include immersive virtual reality applications operated through head-mounted displays and hand-operated controllers. Other presentation formats can be simple, such as images or videos, or more complicated, like augmented or mixed reality applications, or even 3D printed models.

6) Second Interpretation

After the communication format is chosen, the second interpretation is designed. This means that a storyline is given to the visualisation. Depending on the chosen communication format, the storyline can be either very simple or complex.

For example, images have to convey the story through one depiction only, videos usually have a linear storyline and virtual reality applications can even have a non-linear character-driven storyline.

7) 3D model adjustment

The decision to use certain communication formats and the storyline affects the 3D modelling process. The storyline informs which specific scenes, characters and events, and further which camera positions and paths are chosen. An appropriate musical background should also be chosen, too. The already-designed 3D model can now go through several refinements. For example, for still images, camera positions are chosen and the part of the model close to the camera is refined in detail, while the parts in the background can have a simpler design. The same is true for videos, where the 3D model is refined along the camera path. For virtual reality applications, on the other hand, the 3D model usually has to be simplified for virtual reality applications to ensure the smooth running of the application. Here the details can be presented in the textures of 3D models.

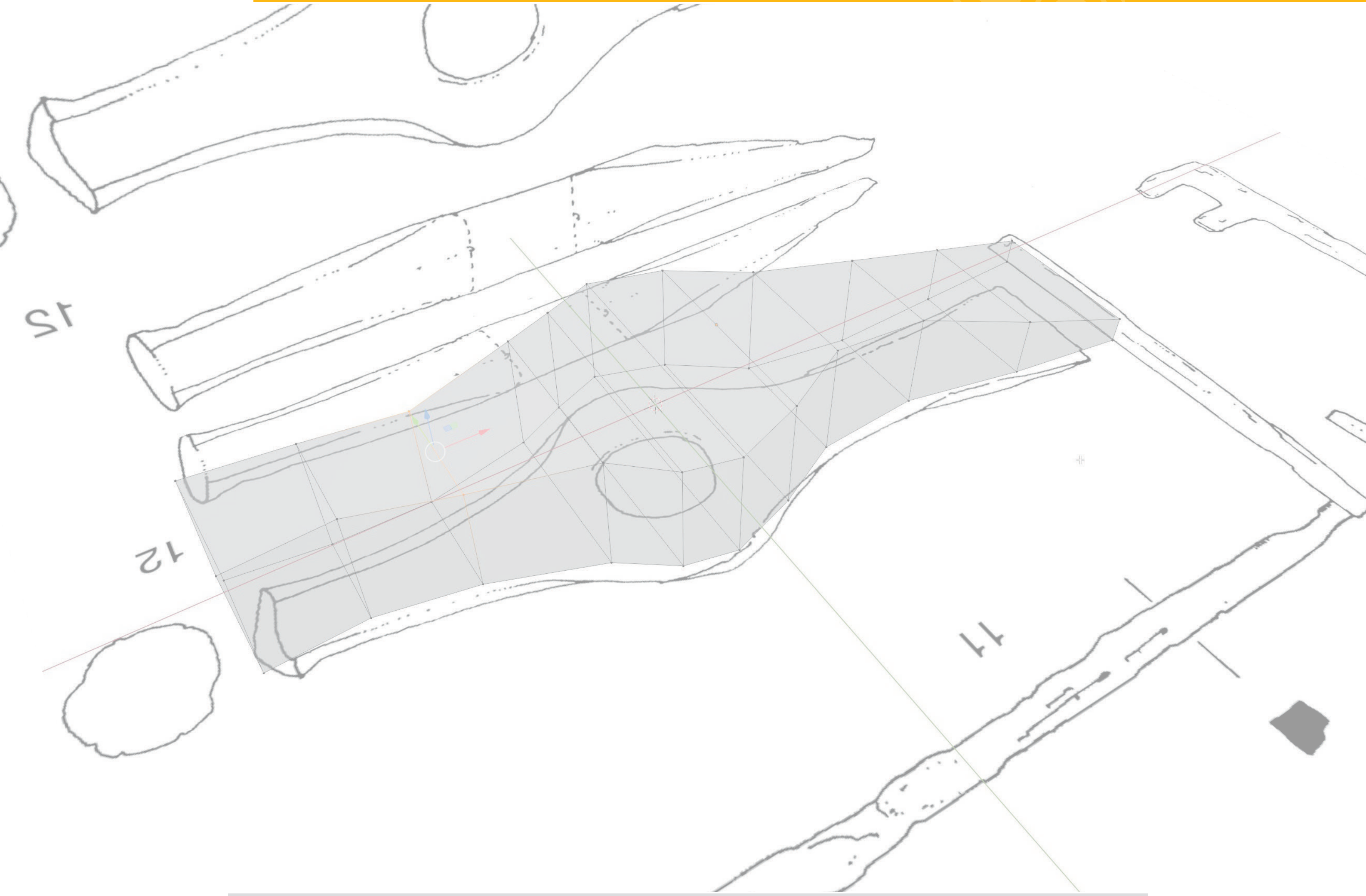
8) Dissemination

In the end, dissemination products are generated, rendered, compiled or uploaded to a 3D viewing platform. These are images, videos, interactive 3D models, and AR or (immersive) VR applications. Then they are disseminated according to the communication plan.

9) Documentation

The documentation of the visualisation process is a parallel process that follows its own rules discussed in the project strategy. To be scientifically transparent, the source data and the visualisation process must accompany the final visualisation. This can be achieved in several ways – intertwined in the video, on a different plane of an interactive environment, additionally on the associated data platform, or communicated in person at various talks.

3 BEST PRACTICE EXAMPLES FROM THE PROJECT



In the following chapter, partners of the Danube's Archaeological eLandscapes project present their experience in making digital visualizations of the archaeological heritage they chose to present. During the project, the museum partners each made their own visualisation(s) based on the workflow we have proposed. We have selected some partners to present their way of tackling the stages of the workflow so readers can get practical insights into the process of the development of their visualisations.

STAGE 1:
PROJECT PLANNING: SELECTION OF ARCHAEOLOGICAL (CULTURAL HERITAGE), TECHNICAL, AND SOCIAL STRATEGIES

Marko Mele,
Universalmuseum Joanneum

Introduction

The main aim of Danube's Archaeological eLandscapes is to make the archaeological heritage, especially the archaeological landscapes of the Danube region, regionally, nationally and internationally more visible, by involving state-of-the-art virtual reality (VR) and augmented reality (AR) technologies. The development, planning, financing and implementation of this project can therefore be used as an example for planning processes for future virtual presentation of archaeological landscapes. "Virtual archaeological landscapes of the Danube region" (Danube´s Archaeological eLandscapes) is a project co-financed by the Interreg Danube Transnational programme, and therefore follows a series of rules for the project implementation and documentation.[5] Interreg projects are usually more complex than most archaeological projects. Thus, some rules are not applicable to a smaller project, but the general structure of the documentation can often be used for such projects. This paper presents some basic steps used in the development of the Danube´s Archaeological eLandscapes project, with a focus on the parts connected to the creation and dissemination of the visualisations of archaeological landscapes in the Danube region.

From idea to a proposal

Ideas are easy to find, especially today, due to the vast amount of information and the ease of accessibility online. The first project idea for the Danube´s Archaeological eLandscapes project was originally discussed in the framework of a cooperation in the preceding DTP project Iron Age Danube. The partners used their existing connections with other experienced and reliable institutions in their countries, and in the broader region, to build a balanced partnership for the new project proposal. To develop an idea into a concrete project is hard work and requires quite a lot of specialised knowledge and experience. Typically two kinds of competences are needed: content and management.

In the case of EU-projects, the content competence mostly derives from the partner institutions. In the Danube´s Archaeological eLandscapes project, the partnership consists of institutions with a wide range of complementary expertise and experience in the field of archaeological heritage, covering 10 countries of the Danube region. The backbone of the project are some of the major museums of the region operating at country/state or regional levels. They each host some of the most important archaeological collections of the region, attracting cultural tourists. Other partners specialising in research and protection, as well as interpretation and visualisation of archaeological landscapes, provide other important cornerstones of the project. Monument protection offices play an important role in supporting work on transnational routes, while research partners provide the technical expertise needed. The

[5] https://www.interreg-danube.eu/relevant-documents/documents-for-project-implementation (accessed 28.2.2022).

project includes associate partners from local and regional governance, tourism and promotion of cultural heritage, who pay special attention to the promotion of landscapes in the form of heritage routes. Due to the diverse composition of the partnership, the project brings together a variety of competences which can tackle the different challenges of the archaeological heritage, and ultimately provide the requisite expertise for reaching the project's goals.

Management competence is another key element of successful project preparation and implementation, but is often overlooked when considering what resources are required for a project. Preparing an application and managing all administrative processes until all documents are signed and an Interreg project can start, takes approximately three months for an experienced project manager with full institutional support. In the course of preparing the Danube´s Archaeological eLandscapes project we could rely on core partners with experience in the implementation of the transnational Interreg projects. Many other partners however, have had little or no experience with such programmes, which meant that they needed support in developing their management structures. This issue has already created challenges when it comes to the process of preparing the project proposal, since it requires more meetings and support for inexperienced partners.

The project proposal in the Interreg programmes is composed of different work packages. In addition to the management and communication work packages, we added three content work packages (T 1-3). Many elements in the Interreg programmes are predefined. For example in the case of the Danube´s Archaeological eLandscapes project: a strategy, tools, pilot actions and learning interactions. The programme also predefines general target groups. The overall goal of the project needs to be in line with the programme goals, but still offer enough possibilities for innovation.

Once the project has been planned, it can be submitted to different financing programmes. Selecting the correct financing source is crucial, since the content needs to be in line with the programmes goals. Knowing the programme priorities and the operational programmes is very relevant, since it can save some ressources. For example, we can consider the three calls of the Interreg Danube Transnational Programme in the financing period 2014-2020. The First call for proposals had 576 Expressions of Interest for projects. 100 Expressions of Interest were invited to submit an application form. 91 application forms were submitted for the second step. 54 projects were finally approved by the Monitoring Committee. This means around 10% of the project ideas were actually implemented. The second call for proposals had 119 proposals submitted, and 22 projects were approved. 276 Expressions of interest were sent for the third call for proposals. 61 applications were submitted and 35 projects implemented.

Financial planning

The creation of the European Union led to the development of different funding mechanisms that allow the Union to invest in different areas, including cohesion and regional development. The investments, which should create added value at European level, are awarded via various funds. The large funds, which cover different areas, are divided into various EU funding programs responsible for the implementation of the projects. For example, the Territorial Cooperation (Interreg) is financed from the European Regional Development Fund (ERDF/ERDF) and the LEADER program from the European Agricultural Fund for Rural Development (EAFRD/EAFRD). In addition to the financial resources from the EU funds, national, regional, local public or private funds are also provided to projects, mostly at a small scale.

Most of the funding sources reimburse staff, administration, travel, external and investment costs. For any project in digital archaeology the most relevant costs are staff, external and investment. In the Danubes´s Archaeological eLandscapes around 53% of the total budget is connected to the staff, and 29% to external costs. Only 4.5% of the total budget covers investments in equipment. Such budgets are normal for transnational projects, where content rather than investments are supported. Higher staff costs are mostly connected to activities beyond the making of visualisations, like developing strategies and standards, organising events and meetings, making the exhibition etc. In work package T2, where the creation of the visualisation is planned, the external budget accounts for c. 50% of the overall budget, while the rest is spent on staff and administrative cost used for content creation, events in the frame of curators mobility actions, and supporting the developers. Most of the partners use external firms to develop digital visualisations of archaeological landscapes, and therefore use the external budget. When developing a budget for a single project for internal sources or national co-financing, the ratio between the staff and external cost usually shifts in favour of external costs, since most heritage institutions do not employ IT-developers. This is sometimes problematic, since changes in the IT market are very fast. Planning a project budget up to two years in advance may create difficulties in the project implementation phase.

Transnational collaboration accumulates competences and knowledge from different institutions. The accrued synergies might save some costs. In the case of the Danube´s Archaeological eLandscapes project, a synergy between museums and technical universities is offering us new opportunities.

Let’s go! – implementation and documentation

Once the project starts, the project team usually needs some time to become accustomed with the goals, milestones and financial aspects of the project. Some activities developed in the project proposal need to be specified, and others changed. During the implementation of the project, budgetary changes might also be needed. We usually underestimate the amount of work needed for internal meetings, contacting specialists for specific questions, the administrative efforts needed to place orders, organise meetings and prepare minutes, documentation of the project etc. These management issues may also emerge in much smaller projects dealing only with the development of individual digital products, since these projects still need to prepare internal reports and look after external communications. Generally speaking though, the more complex the project, the greater the challenge.

There are many different project management tools available on the web. You can even create your own. Ultimately, it comes down to the efforts of the project manager invested in the monitoring and steering of the project, and the motivation of team members to achieve the best output possible. In most cases involving the development of new digital products, the team needs to cooperate with an external firm. It is recommended to take the time and the effort to collect offers from many different companies, taking in consideration not only the price but also the references.

In the case of the Universalmuseum Joanneum, we are developing visualisations of two periods in one landscape (Southern Styria). The sites selected are the Iron Age settlement of Großklein and the Roman period city of Flavia Solva in Wagna. The selection of the sites for our institution was quite easy, since they are the most prominent archaeological sites in Austrian Styria. Additionally, artefacts from these sites form a large percentage of the museum's archaeological collection. Furthermore, for almost 200 years, the museum has been involved in the research of these sites. From an archaeological and social (political) standpoint, the combination of prominents site, long-term research projects, and the comprehensive publication of the finds are always a good choice to start with.

Before opening the tender procedure for programming the visualisations, we organised content development workshops with participants from different fields interested in the topic. Developing a solid "script" and supporting it with visualisations (photos, drawings, plans) is the most important step for getting a clear and sound offer from a development firm. We contacted nine companies with the script, and held individual meetings in order to obtain suitable offers. IT-Products in particular can be risky expenditures if all details are not defined upfront. We received four offers from the nine companies we contacted. After renegotiating with the two firms who provided the best offers we placed the order.

We are done! – procedures after the project conclusion

In the summer of 2020 the Danube Archaeological eLandscapes project started, and in the winter 2022 it will end. Our experience from previous projects means that the end of this project doesn't mean the end of the management work. The first task is to secure the refund of all activities, which means the preparation of project reports and "wrap- up documents". At the same time, we will try to find other ways to further use the project outputs. Sustainability is one of the main aims of most projects, but not easily achievable.

A successful example of how to upgrade a transnational Interreg project to a permanent collaboration is the case of the Iron Age Danube route.[6] This cultural route devised by the Council of Europe was built on the outputs of the Iron-Age-Danube project.[7] The project focused on the research, protection and promotion of early Iron Age landscapes. After the end of the project the tools, including a database of sites, a visitors' app, digital e-learning tool and display boards at the sites were adapted to the need of a cultural route. By establishing sound management of the route through the establishment of a legal body called the Iron Age Danube Route Association, it is hoped there is a bright future for the project.

The question of sustainability is also an important one for developing digital tools. Today's digital tools change so fast that heritage institutions struggle to keep track of development, to say nothing of investing in the emerging features. In reality, the heritage sector can´t really compete with the entertainment industry in the digital sector, but the museums and other heritage institutions may be able to offer a combination of hands-on and digital experiences supported by a transfer of knowledge. Therefore, considering what should happen with a product in three, five or ten years is a relevant question; even if it seems at the moment that a project's graphics will be unimpressive, the playability low, the equipment not working, and that it might sooner or later land in some kind of metaverse.[8] In the Danube´s Archaeological eLandscapes project, we also hope to obtain some guidance to the question by asking the visitors in transnational surveys.

[6] https://de.ironagedanuberoute.com/ (accessed 28.2.2022).
[7] https://www.interreg-danube.eu/approved-projects/iron-age-danube (accessed 28.2.2022).
[8] https://en.wikipedia.org/wiki/Metaverse (accessed 28.2.2022).

STAGE 2:
DATA ACQUISITION

Andrew Lamb,
Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart

Data Acquisition and the Danube Archaeological eLandscapes

As part of the process of creating a strategy and determining the standards used for digital reconstructions and visualisations of archaeology, the Danube Archaeological eLandscapes commissioned a three-part internal study entitled Interpreting Archaeological Data for the Creation of Digital Visualizations. The study sought to establish a uniform set of standards by which all partners would operate when creating their visualisations. It consists of three parts, each dedicated to a different aspect of the visualisation process and experience: Social, Technical and Archaeological. The latter two were used to inform the process of data acquisition.

The Archaeological Study outlined a series of criteria against which the quality of data from sites considered for visualisation should be assessed. These include when sites were investigated, and what type of analyses were undertaken on the data. For example, post-war excavations were deemed to have produced higher quality data, whilst the criteria used to assess data was dependent on what type of material was examined; techniques used for landscape archaeology are unlikely to produce many useful results for artefacts. The feasibility of a number of archaeological sites within the Danube Archaeological eLandscapes project area was already examined in this study. This account focuses on the Early Iron Age (c.800-475BC) burial VI at the Hohmichele, Lkr. Biberach, Baden-Württemberg. The Danube Archaeological eLandscapes' Archaeological Study Group previously recommended a desk-besk assessment of this site, in order to improve the quality of the visualisation of sites around the Heuneburg.

Within the context of southern German museums, digital content is almost ubiquitous among those institutions who responded to the Technical Group study in 2021 (n=29).[9] German institutions enjoy certain advantages in terms of data acquisition, including excavations being conducted and published to generally high standards, and improved access to researchers and artists with the relevant skills. At the same time, German institutions continue to experience many of the challenges encountered by other Danube Archaeological eLanscapes members attempting to produce visualisations, in particular budgetary constraints.

The Hohmichele: An example of data acquisition

The data used in the reconstruction of the Hohmichele grave chamber were acquired from excavations conducted between 1936 and 1938. As such, they employed none of the more modern techniques used elsewhere in the Danube Archaeological eLandscape: LIDAR, Active Near Sensing Techniques, SFM-MVS etc. Rather, this is an exercise in legacy data. Although these excavations were scientifically conducted, by inter-war standards, there is nevertheless an ethical issue. The 1930s excavations at the Hohmichele were conducted by the SS "Deutsches Ahnenerbe" (German Ancestral Heritage). This was an official Nazi organisation responsible for number of important excavations in Germany during

[9] In the scope of the Danube's archaeological eLandsapes' internal Technical Group study, museums throughout the project regions were interviewed for their state, plans and wishes on the topic of digital equipment and digital presentations.

the 1930s. As a result it was ideologically driven, and sought to create (invariably artificial) links between prehistoric German archaeology and the Nazis' vision for the Reich. In doing so, academics who were National Socialist and German Workers Party (Nationalsozialistiche Deutsche Arbeiterpartei; NSDAP) members, or at least subscribed to the Nazi ideology, were invariably promoted over their colleagues, and were often given the directorship of important excavations. This includes the director of the Hohmichele excavations: Gustav Riek, NSDAP member since 1929. As such, we must be aware that these excavations, and the data obtained from them, were conducted with a clear ideological bias; one that often distorted the data to fit a narrow view.

Circumstances, however, prevented the Hohmichele becoming a Nazi monument. The first is that the central burial chamber (Grave I) was looted in antiquity. Although the artefacts found in Grave VI, including parts of a four-wheeled wagon, quiver with arrows and bronze vessels, hint at the former wealth of the grave, it was less than what the "Ahnenerbe" had hoped to discover. Secondly, and more importantly, the Second World War began before the Hohmichele could be published. Fortunately the 1930s excavation records survived the war and were finally published, minus ideological distortion, in 1962 (Riek and Hundt 1962).

The decision was taken to produce an interactive 3D model of the burial chamber as it would have appeared immediately after the deceased had been interred. This decision was based on a number of reasons:

- The Hohmichele is one of several burial mounds located near the Heuneburg and Danube valley.
- Although the Hohmichele is not the closest to the Heuneburg, it was one of the burial mounds whose central chamber was not investigated in the 19th century, and for which an excavation plan and complete catalogue of surviving grave goods survives.
- Due to its sheer size, the Hohmichele has one of the greatest potentials to be presented to the public as an example of a monumentalised landscape component.[10]

The Hohmichele is it appears today

(Landesamt für Denkmalpflege Regierungspräsidium Stuttgart. Photographer: R. Hajdu).

[10] According to the Danube's archaeological eLandsapes' internal Archaeological group study.

Other graves in the Hohmichele group, and adjacent features, have been excavated since the 1960s (Dehn 1971; Bettina 2000; Hansen et al. 2015). However, the 1930s excavations were so extensive, that the sole source of data (aside from the physical artefacts themselves) for Grave VI is the 1962 excavation report (Figure 2). In spite of the circumstances surrounding the excavation, the published account of the site is sufficiently detailed to permit an accurate 3D reconstruction. For example, it contains a complete catalogue of grave goods, including the aforementioned 50 iron arrowheads found in a quiver (Riek and Hundt 1962, Plate 10, nos 161-211). Thus, the burial chamber meets the criteria set out by the Danube's Archaeological eLandscapes project's Archaeological group for creating an accurate 3D reconstruction.

The 1930s excavations of Hohmichele Grave VI illustrating the scale of the excavations

(Riek-Hundt 1962, Plate A.2. ©Universität Tübingen, Institut für Ur- und Frühgeschichte und Archäologie des Mittelalter.)

From data acquisition to transferal

With the relevant data acquired from the excavation report, the next stage was to transfer this information to the artist responsible for producing the reconstruction. This was done by providing relevant images and extracts from the excavation report, along with supporting text extracts and explanations. The challenge of interpreting the grave and creating a visualisation of how it would have appeared at the time of burial is the topic of the next section.

STAGE 3: **DATA INTERPRETATION**

Andrew Lamb,
Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart

The previous section described the data acquisition process for the Hohmichele visualisation, and how this process relates to the wider standards set by the Danube Archaeological eLandscapes. This section considers how the data for the Hohmichele were interpreted, and its place within the wider Danube Archaeological eLandscapes project. If data acquisition (traditionally through excavation) is one side of archaeology, data interpretation is the other. Interpreting data is not a simple process. It must be remembered that archaeological data are fragments of the past. Even in instances of exceptionally high levels of preservation, such as the Brone Age settlement at Must Farm, Cambridgeshire, UK or Iron Age burials from Pazyryk, South Siberia, Russia, details are missing. In most cases, however, archaeologists deal with datasets which are largely incomplete. Naturally, this creates challenges when interpreting the data.

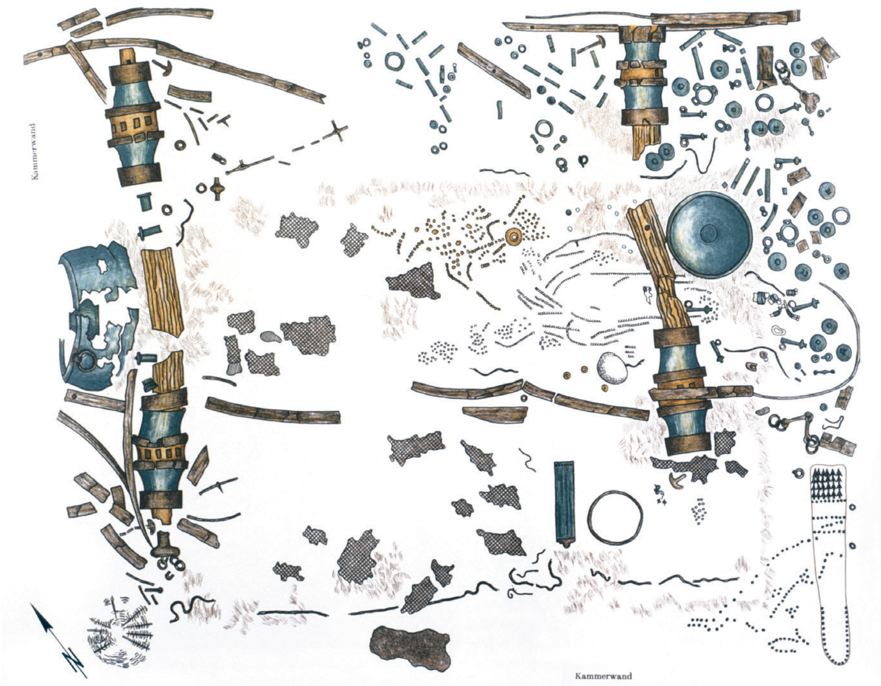
In order to address these gaps in the dataset, archaeologists have relied on theory to bridge the gap between surviving datasets and past realities. Within the Anglosphere, this idea is perhaps most strongly associated with Lewis Binford's (1977) idea of middle range theory. Modern theoretical discussions within archaeology are wide-ranging, international and vibrant; thus offering a range of tools for interpreting data (cf. Kristiansen et al. 2015). Theory has also had a historically distorting effect on archaeology. In the previous section it was noted that many sites in 1930s Germany were excavated by members of the NSDAP, and thus interpreted according to Nazi ideology. The distorting effects of political ideologies are not limited to Germany, and occur elsewhere in the Danube Archaeological eLanscapes project area. This includes sites in Romania excavated under the Ceaușescu regime (Ellis 1998, 223) and the former Yugoslavia at different points in history (Dzino 2010, 29). Such distortions are no longer current in professional and mainstream archaeology. Nevertheless, they may play a role in legacy data, and public perceptions of the past; something which should be borne in mind when attempting to produce a publically accessible visualisation.

Rather than subscribe to a specific theoretical perspective, the Danube Archaeological eLandscapes has sought to provide a guide to best practice when interpreting archaeological data. The guidelines for this appear in the Archaeological Study group's internal report. A key challenge identified in this study is how the process of interpretation can be explained to the public when visualisations are displayed. A recurring trope of popular archaeological television programs is that the presenters are provided with a fragment of an object, and then extrapolate an entire artefact and purpose ("ritual" being a cliché) from the fragment. Usually no explanation is given as to how the archaeologist knows that the fragment originally belonged to a particular artefact, and how archaeologists have come to realise the purpose behind different artefacts.

Visualisations must thus make it clear that what the public are looking at is an interpretation based on the current state of research. Additionally, any gaps in the data acquisition should be noted. In order to determine if a Danube Archaeological eLandscapes site is a suitable candidate for a visualisation to be produced, the authors of the report produced a matrix against which DAeL partners tested their sites. The Hohmichele Grave VI scores between 60-80% in this matrix, in spite of the circumstances surrounding its excavation and discovery. It is thus, according to the Danube Archaeological eLandscapes standards, a suitable site for visualisation.

Hohmichele Grave VI: Interpreting the Data

As noted in the previous section, a number of challenges existed regarding data collection. These include the pre-war date of the excavations, the organisation responsible for the excavation, and the fact the site had been subject to looting. There is the additional problem that the soils in this part of Germany are not conducive to the preservation of bone. Fortunately, what remained was sufficient to produce a visualisation (Figure 1). Furthermore, Hohmichele Grave VI displayed a number of features observed in other elite Hallstatt graves, thus lending support to the proposed interpretation. However, it was decided not to import elements from other graves, at the risk of producing an inaccurate visualisation.



Plan of Grave VI when it was excavated (Riek and Hundt 1962, Supplement 3).

(Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart).

Hohmichele VI is a wagon grave. Such graves are well-attested in central Europe and eastern France (Pare 1992, fig. 4), and allow inferences to be made about the original arrangement of Hohmichele VI for the sake of the visualisation. It cannot be said for certain if the preserved grave goods are in the original position they were placed; post-mortem movements invariably affect the location of grave goods. Some of the objects, namely the wagon and copper-alloy vessels, are heavy enough that they were likely discovered in the original locations they were located in. Additionally, the sex and gender of the deceased, a male and a female, was inferred by Riek and Hundt (1962, 65) based on the presence of gender indicative grave goods, rather than an osteological study. Indeed the only osteological material to have survived was tooth enamel. This approach of inferring gender from grave goods is no longer current. Indeed, prior to c.550BC, gender ambiguity was recurring phenomenon in Early Iron Age graves in this part of Germany (Pope 2021, 33). One aspect of the reconstruction where we can be reasonably sure of accuracy is colour. In addition to the grave goods with predictable colours (copper alloy vessels, the wooden chamber, iron fittings), textiles were preserved. These textile fragments can inform us both about the materials and weaving techniques used to produce them and, in some cases, they even retained traces of colour (Riek and Hundt 1962, 204).

Data Interpretation in Summary

This short section has sought to highlight some of the challenges that archaeologists face when interpreting data. The observation that even the best-preserved sites represent only a fraction of what once existed is perhaps the most obvious challenge. Theoretical tools and comparisons with other sites with other sites may fill in some of the gaps. At the same time, if a visualisation is intended for the public, it must make it clear what aspects of the visualisation are based on hard evidence, and what is inferred. This is something that the Hohmichele visualisation has tried to do. The surviving material is comparable to other high status Hallstatt wagon graves, whilst the fortuitous preservation of textiles permits us to reconstruct what the occupants would have worn. At the same time, interpreting the gender and sex of the deceased based on grave goods alone is an approach that is increasingly advised against. It is only once the interpretation of a site has met the criteria set out by the DAeL that archaeologists can proceed to the process of producing a visualisation. This is the topic of the next section.

STAGE 4:
EXAMPLE A: DRONE-BASED 3D MODELLING OF ARCHAEOLOGICAL LANDSCAPES

Tamás Látos,
Hungarian National Museum

In recent years the amateur and professional usage of drones have become part of our everyday lives. Processing drone data in archaeology and heritage protection helps to map, and thus make more visible, excavations. This in turn enables the discovery of archaeological connections faster and more often, thereby enabling archaeologsts to better record and preserve the phases of ongoing excavations. The advantage of unmanned aerial vehicles (UAVs) is that they can be used to map a large area relatively quickly. Also, they enable us to analyse the wider environment of the site or discover new archaeological objects in an extremely cost-effective way. Furthermore, using drone recordings, a three-dimensional landscape model can be created that can also be used later for exhibition purposes. Through the latest AR and VR technologies, visitors can immerse themselves in the original environment, discover the former natural landscape that existed thousands of years earlier, or capture the 3D likeness of an artefact that has been displayed, and create a real connection with the content that museums want to present. The main goal of our work was to create a high-resolution 3D model of the Villa Romana Baláca to serve as the database of the VR technology which will be completed during the Danube Archaeological eLandscapes project.

As an initial step, we created a flight plan and considered whether to use the DJI Pilot app or the DroneDeploy app to follow the flight plan. In this case, we opted for the latter as it is a free application that is available on the internet from any browser.[11] To begin with we had to search our survey area, which in this case, is located next to Nemesvámos village (Veszprém county). Using this map, we could draw a polygon of the area to be surveyed. The next important step was to set up the camera, specify the flight altitude and ensure an overlap in ratio between the pictures.

Flight plan generated by specifying the area to be surveyed, flight altitude, camera parameters, and overlap between images.

[11] https://www.dji.com/si/downloads/djiapp/dji-pilot (accessed 28.11.2022)

We used a DJI Matrice 600 pro drone, and a DJI X5R camera which takes 16 MP images. After the camera had been set up, we set the flight altitude to 50 m, and accepted a 70-75% overlap ratio, which is the default value in the app, as these values are the minimum limit if we want to create a good 3D model with photogrammetry. As a last step, we included the Enhanced 3D option in order to add perpendicular paths to the plan, which will ensure that the model would be better if the images were taken from multiple angles. With the flight plan agreed upon, we could stipulate the flight time, how many pictures would be taken, and figure out how to upload the plan to the drone.

The next step was flying over the field. We added GCPs (ground control point) in the survey area. These photo markers help in georeferencing. They are simple black and white paper markers with a number which is visible on the pictures. The central point of the GCPs is measured with RTK (real-time kinematic) GPS. We prepared the drone, the camera, and checked the flight plan, and over the course of 20-25 minutes the drone operated independently of additional input. After the programmed flight plan, we completed a second flight over the area with the camera set to a tilted position, as there are many places in the area which are obscured by trees or roofs. As such, we tried to collect additional data for these locations. The fieldwork took 1.5 hours to complete.

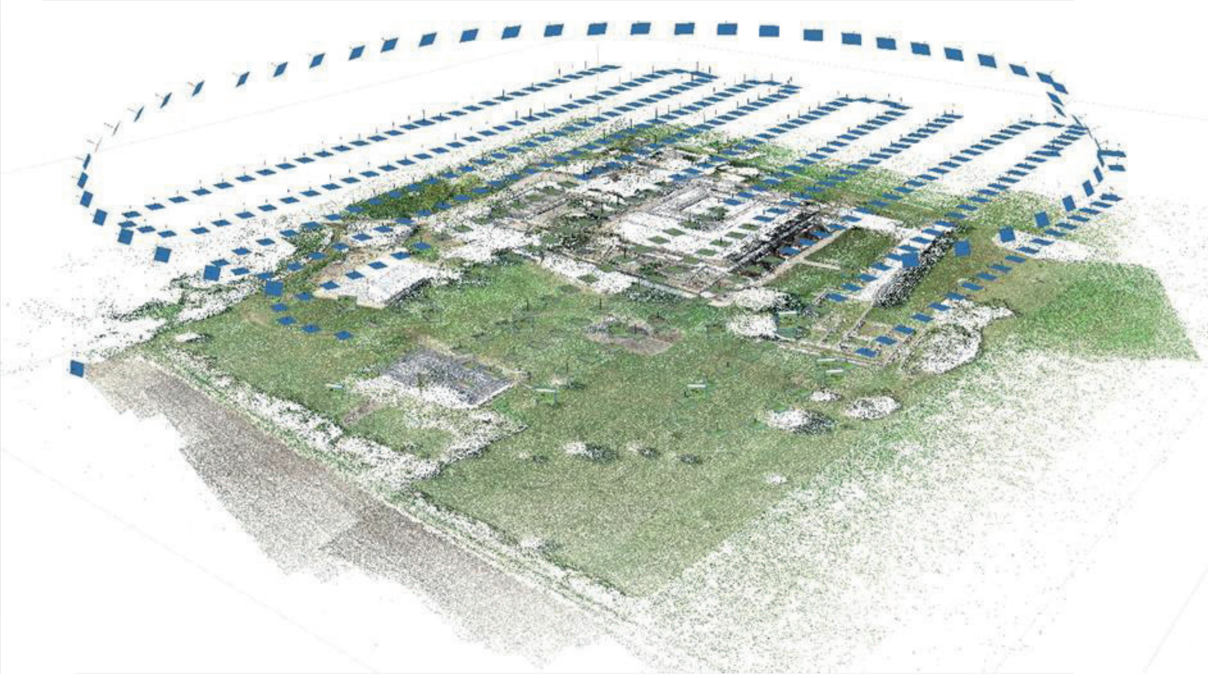
Following this, we uploaded the images and data from the RTK to the computer. The next step was data processing, for which we used the photogrammetry software Photoscan[12] (Metashape). We took 441 pictures, and uploaded them to the software, accounting for brightness and contrast equalisation. We then ran the first process, which was the alignment of the photos. The software works by finding the common points between the images and fitting them together. It then defines the spatial positions of the points and creates a sparse point cloud.

For the next step we generated the dense point cloud. The software localises the spatial positions of the points as far as possible. After this a mesh is generated from the dense cloud. The app interpolates the values between the points and fills the holes in between them. This is the basis for the 3D model. We could now add the GCP-s to the model and give them the measured values so that the model was spatially accurate. The last step was to give texture to the model from the photos. If it was required, we could also make an orthophoto, or a DEM, from the model. Once the software had identified all the identifiable points and used them to assemble the images, it created a three-dimensional, so-called, rare point cloud from them (Figure 3).

After this, the next stage in generating the 3D model was to fill this - still incomplete - data set by generating a dense point cloud. The software determined the spatial position of as many points as possible from the merged images. Everything was now ready to create the three-dimensional model. The fact that, in the case of Baláca, the dense point cloud consisted of more than 153 million points is a good indication of the amount of data being created. An algorithm which follows the averaging principle filled the gaps between the points (by interpolation). The final model can also be textured, based on the pixel value of the photographs, resulting in a nearly life-like, rotatable, magnifiable 3D model that can be manipulated for further use (Figure 4).

It is important to place the finished model in the appropriate geographical position, as previously mentioned, and to refine its actual dimensions using the photographed and measured fitting points. The three-dimensional point cloud or model that was created in this way

[12] Agisoft Metashape Professional, version 1.8.4 build 14856 (64 bit)



A rare point cloud generated from drone recordings.

can be the starting point for a virtual reality (VR) environment. The final VR content can add touristic value to the Villa Romana Baláca, and thus to the Danube region.

Virtual 3D model of the central building complex of the Villa Romana Baláca.

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[11] https://www.dji.com/si/downloads/djiapp/dji-pilot (accessed 28.11.2022)

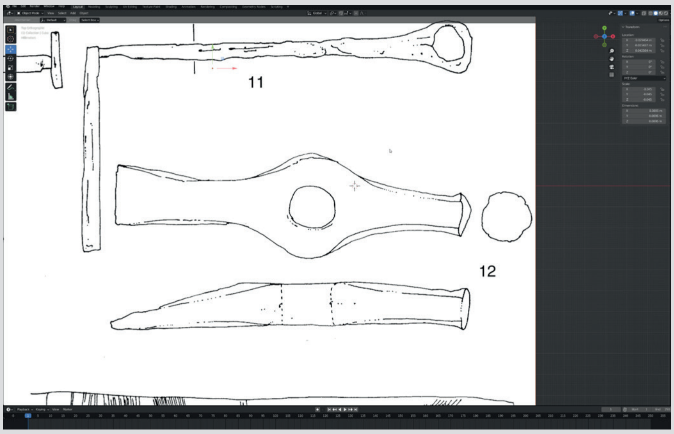
EXAMPLE B:
3D-MODELLING A VIRTUAL RECONSTRUCTION OF AN IRON AGE HAMMER FROM THE ULAKA SITE USING BLENDER

Igor Dolinar and Vesna Tratnik,
National Museum of Slovenia

In the virtual presentation of the Iron Age smithy at the site of Ulaka (Slovenia), we decided to use as authentic objects as possible, so we created 3D models of archaeological objects that were excavated at this site.

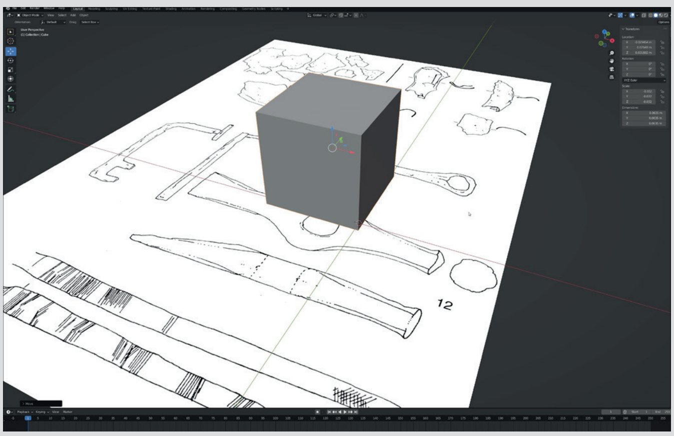
In this chapter, we present an example of making a 3D model of a hammer, using Blender software.[13] With this short step-by-step presentation, we want to introduce the workflow and various options for designing the details of 3D models. The entire process of making such a model, in the way we have presented requires about 3 hours of work.

1.



Begin by placing the reference image into the software's top view and adjust it to the proper scaling.

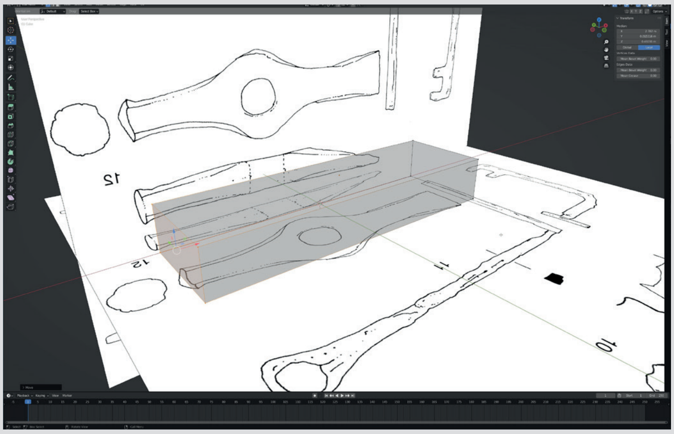
2.



Continue modelling with the Default Cube, the first object offered by Blender upon startup.

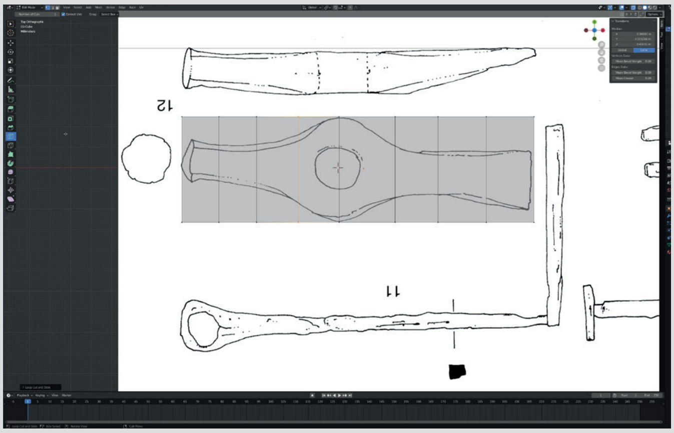
[13] Sources and links: https://www.blender.org/; https://www.youtube.com/watch?v=6UeEUQJGNHY; https://www.youtube.com/playlist?list=PLcpbyAte3x6Y0skyLUZEUKOlqcsFmPpHT

3.



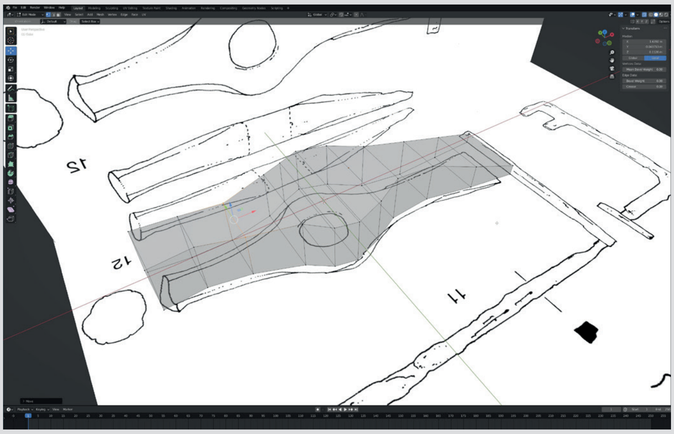
By positioning individual vertices in the 3D space, we tried to match the size and basic shape of the object. This involved placing another reference image in order to set the object's dimensions from the side view.

4.



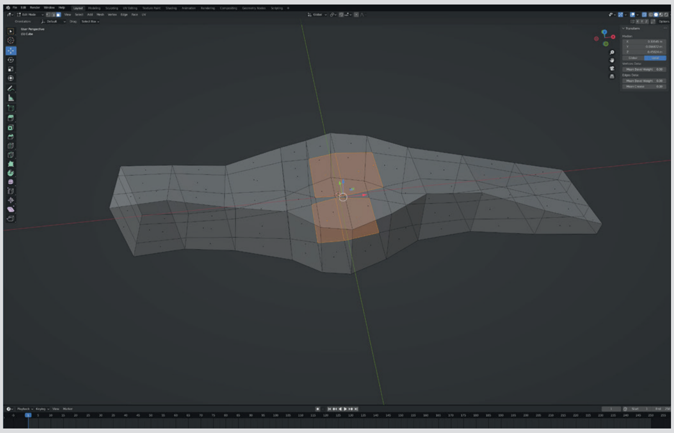
Use the Loop Cut tool to add a few, fairly evenly distributed cuts. This way, we get even more points / vertices to manipulate.

5.



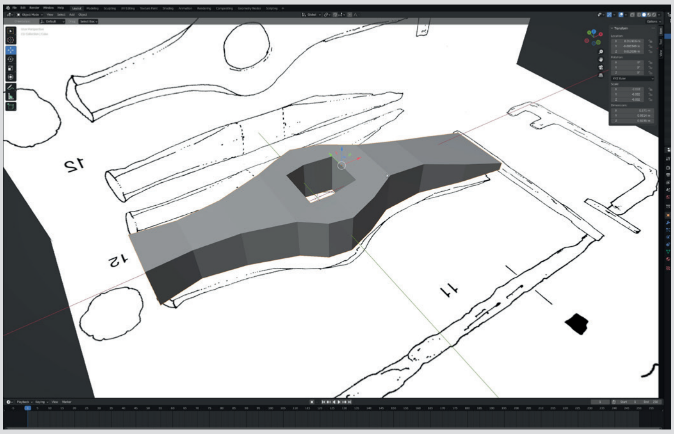
Following the reference image, we move the individual points in order to envelop the shape of the object.

6.



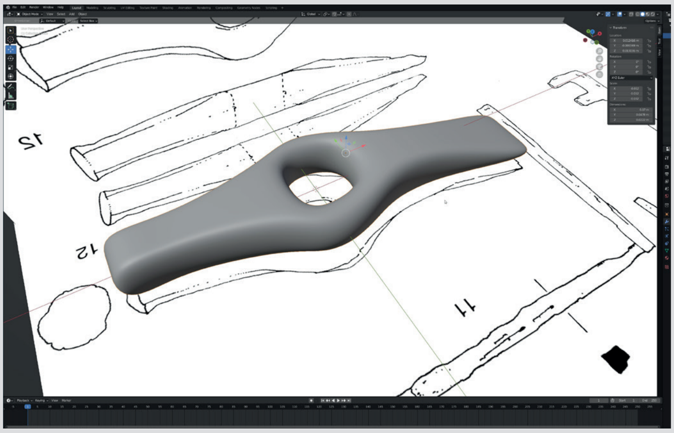
Move on from manipulating the 3D vertices to manipulating the faces. Select the appropriate faces to make the hole in, and then delete them. It is best to already consider this when using the Loop Cut tool.

7.



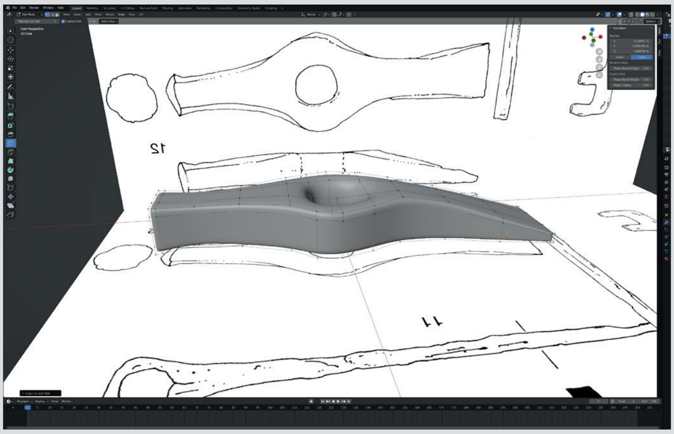
Replace the deleted top faces with new inner faces, which we insert manually.

8.



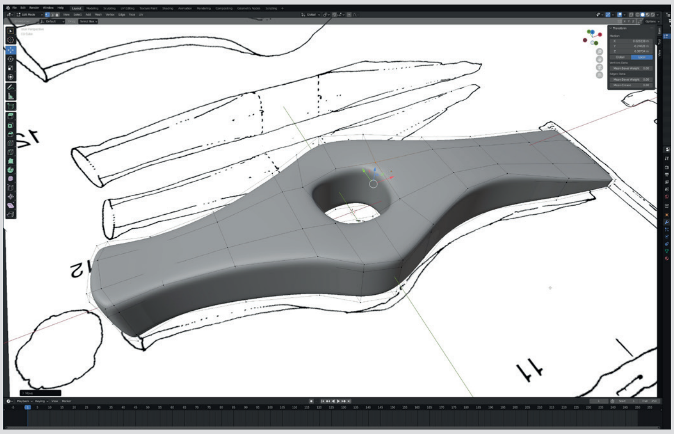
Add a Subdivision Modifier.

9.



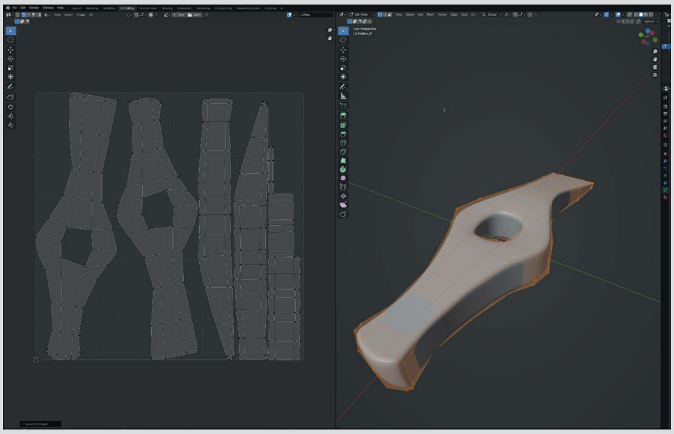
Using the Loop Cut tool, add a few strategically placed cuts to give the edges proper curves, and repeat the same procedure for the hole.

10.



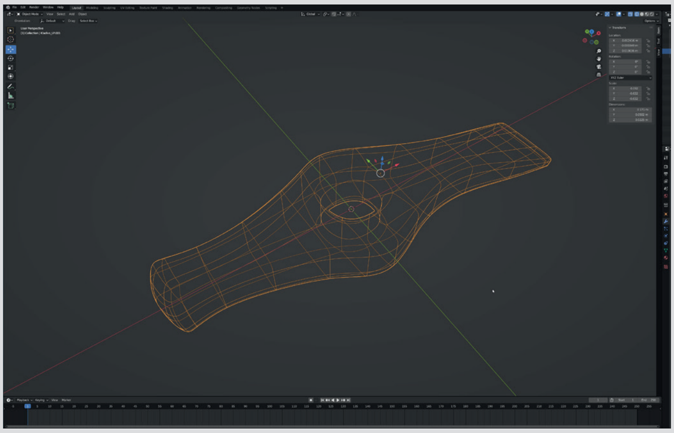
Final 3D vertices corrections. The basic shape is now captured using a minimal number of faces.

11.



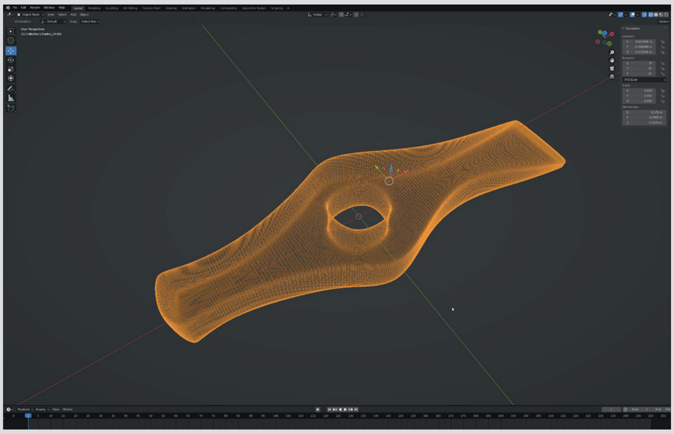
Next is UV mapping. Cut the 3D model up as when making a paper model. In this case, it is done automatically by using Unwrap > Smart UV Project.

12.



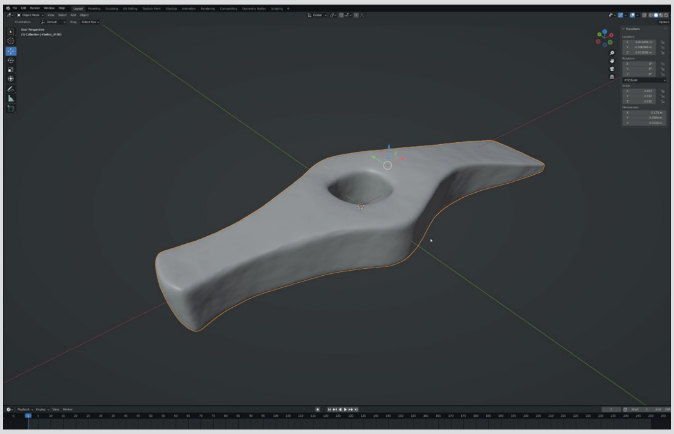
Make a copy of the object; we will modify the original later.

13.



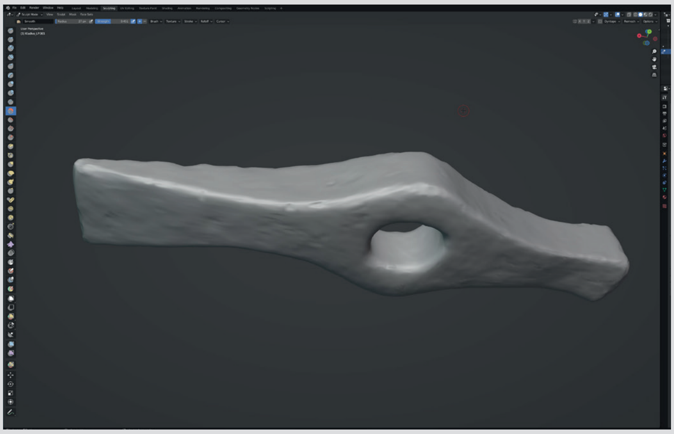
Use the Apply Subdivision Modifier command in the copied object, which provides us with a high-resolution object.

14.



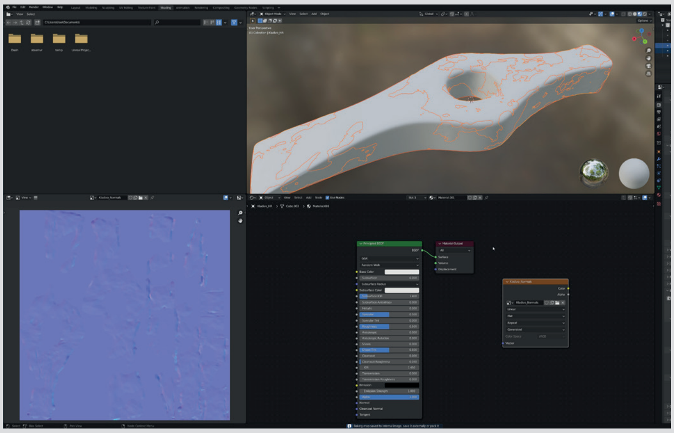
Add a Displace Modifier, and use the Clouds/Noise texture to get a bruised-looking surface.

15.



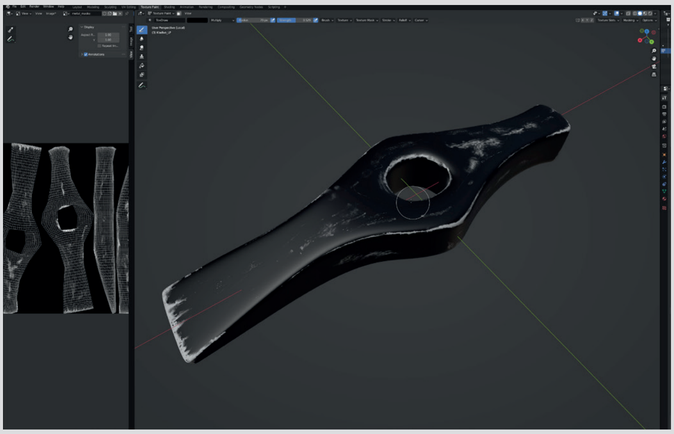
The next phase involves the Sculpting tool. Manually paint the scratches, indentations, etc. It is recommended to use a stylus with a touch sensitive pen. Once this procedure is finished, we obtain a high-resolution 3D model.

16.



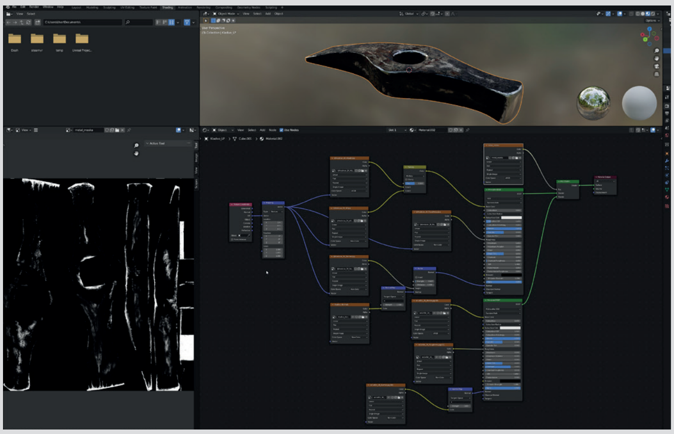
Making a Normal Map, which will be used to create a bruised, scratched look on the surface of our original, low-resolution object. Bake a Normal Texture from the high-resolution object to use on our original. The high resolution object is now no longer needed.

17.



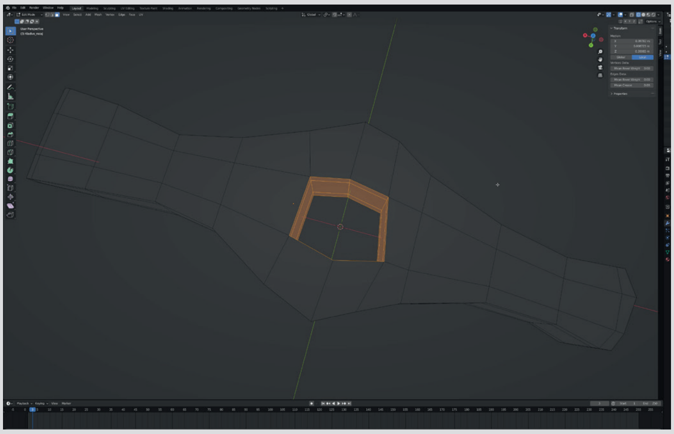
Using the Texture Paint tool, manually draw the mask, which will separate the corroded part of the hammer from the polished part. Attempt to capture the look of the scratched off edges using a stylus with a touch sensitive pen (Wacom). In addition to sculpting, this is the most time-consuming operation. Using the Clouds texture, we also soften the sharp edges and protruding points.

18.



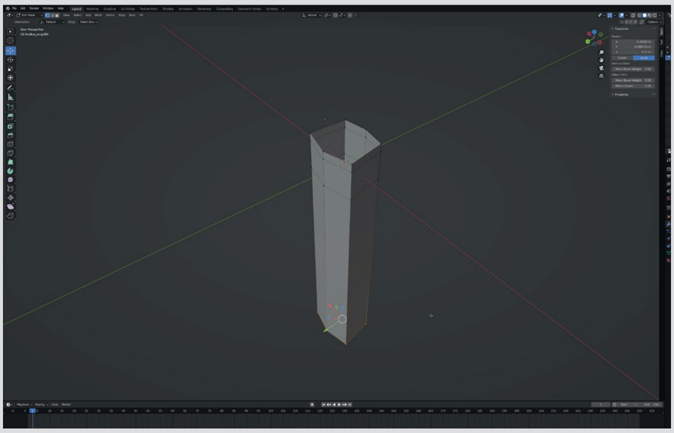
Creating the final texture. Export the shiny, polished metal material from the Quixel Bridge library. The mask we created before defines the border between both materials.

19.



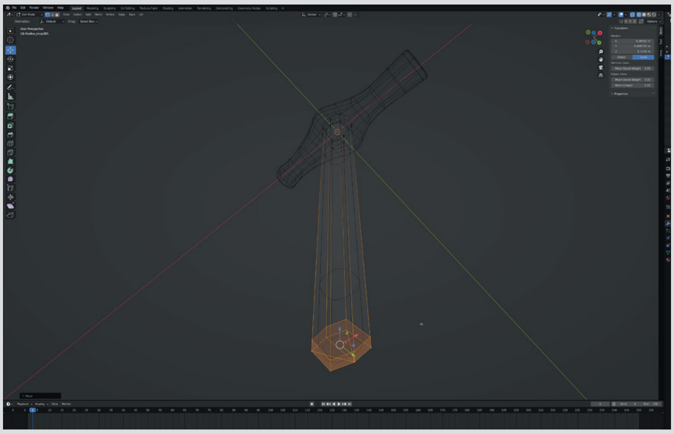
The hammer handle. Create another copy of the original hammer and use the inner faces of the hole as a base.

20.



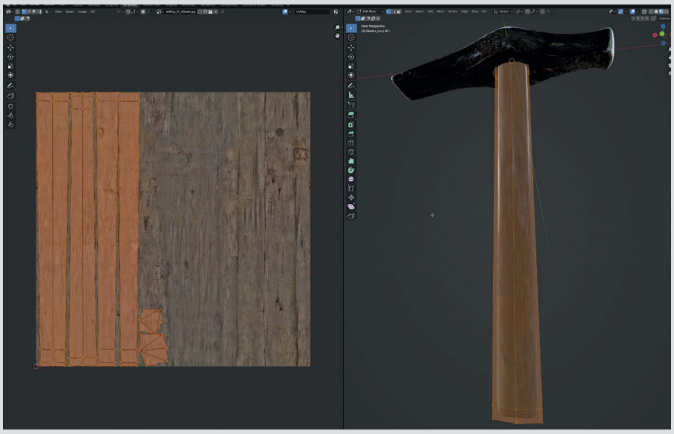
By modifying the 3D vertices, we define the basic shape of the handle.

21.



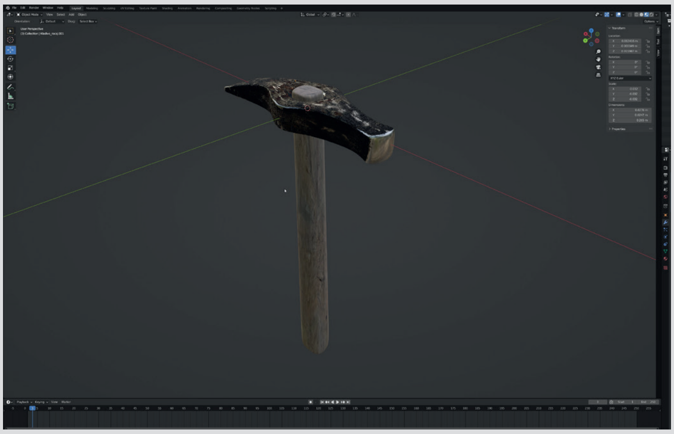
Fill in the empty spaces and use the Loop Cut tool and Subdivision Modifier again.

22.



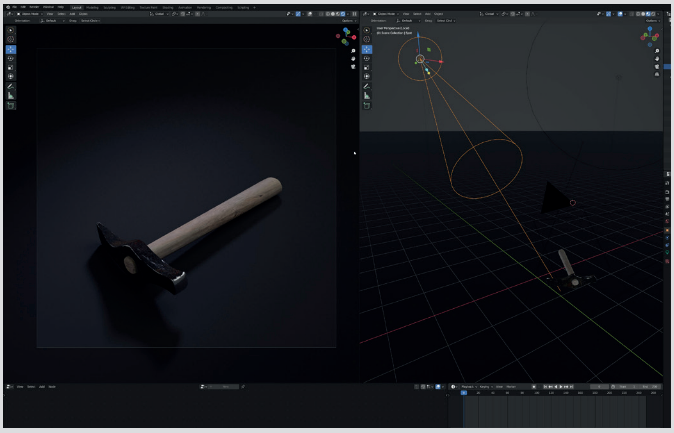
UV Mapping the hammer handle.

23.



The handle consists of only one material; in this case, once again we use a Quixel Bridge material with all the corresponding textures.

24.



Set the background, a few lights, and take a quick studio photo.

Comparing
original
(up)
and 3D
modelled
objects
(below) from
Iron Age site
Ulaka, Slovenia.

STAGE 5:
COMMUNICATION PLAN

Richard Oľhava,
Technical University Košice

When planning which visualisation products to make, a communication plan must be established. This means you have to decide where and how the computer-aided visualisation will be shown. For example, if the plan is to present virtual visualisation at a workshop, accepted communication formats include immersive virtual reality applications operated through head-mounted displays and hand-operated controllers. Other presentation formats can be simple, such asimages or videos, or more complicated like augmented or mixed reality applications or even 3D printed models.

In our case study we would like to present our communication plan, when preparing an Danube Archaeological eLandscapes project travelling exhibition. At the beginning of the process we employed very simple **3WWW** questions which were to be answered in preparation for work on visualisations and the exhibition.

Where? – The exhibition will not be set up in a permanent location but it will be a travelling exhibition.

What? – The Rankovce burial ground.

Who? – We estimated our visitors' compositions and made a rule to follow in all stages. 45 % adult visitors with a general interest in history, 40% child and young visitors (under 15) and 15 % adult visitors with a deep interest in history.

In conclusion, using of all of these answers we were able to make a final plan as to which types of visualisation we would use and how we would present it. All the different types of devices have pros and cons and are suited for different types of visitors and contents.

First of all, as noted, the exhibition would not be permanent, but rather it was intended to be moved between different environments. This meant that we would be unable to produce any kind of classical exhibition with numerous finds and glass showcases. We also discovered that some big 3D printed models and video-mapping technologies would be unsuitable. However, on the contrary, as mentioned our exhibition would not be moving often, our aim was also not to produce an archaeological visualisation show with twenty Oculuses and plastic chairs. The ultimate result of this discussion was to determine which devices to use and which to avoid.

In the case of Rankovce burial ground, due to the nature of the site it was not possible to visualise the site using architectural examples and LiDAR data. Rather, we realised that the only things which could be presented were *graves with finds, ritus, and the excavation itself*. We did not have any known settlements in this area. Also, due to the risk of metal detectorists, it was not possible to publicly disclose the exact location of the site and use certain types of images. During this stage of preparing a communication plan commenced to see which communication formats would be used. For the *graves with finds* we determined that the best options were exhibition panels with 3D printed artefacts and touchscreen applications → image format. Ritus was more complicated because of the lack of precise data, and no scientific way of presentation could be obtained. After some discussions with local archaeologists and 3D artists we chose a virtual atmospheric presentation using the Oculus headset and a simple video. Archaeological research of this site is not finished yet so we saw that as an opportunity to present the terrain work of archaeologists as a simple game app on a touch screen. It seemed that in this stage we began to have an idea which formats we would probably use. The next task was to filter the formats out by considering the type of visitors who would visit the exhibition.

As previously mentioned, for each specific group of visitors we needed to prepare a special type of communication format; the 40/45/15 rule. We tried to follow this rule throughout the entire preparation. When using this rule, the special needs of visitor groups could be filtered to specify the types of communication formats required. It was obvious that we couldn't use virtual atmospheric ritus visualisation for adults with a deep interest in history, as the lack of facts which can be presented in this case precluded this option. Thus we combined panels with more extensive information and touchscreen applications. For adults with a basic interest in history we had to prepare parts of panels combined with some simple information through the AR application. We saw that some groups of visitors still needed to read proper texts and that these groups tend to avoid using specialist technologies. For this reason, we continued to use physical communication formats for each group. In the case of children and young visitors we believed that modern technologies were much more suitable. As a result, we used short and simple content such as animated videos for the children and atmospheric VR visualisation for adolescents. Physical objects were also used for the youngest group of visitors in order to stimulate their attention.

Final communication plan

In summary, all previously mentioned aspects have been presented in such a way that they are clearly understandable. This involved using different communication formats. The final step in this process was to make a kind of general idea of all of the communication formats and contents which will connect all parts. As part of the Interreg Danube programme it was also necessary to think about which aspects could be used to promote and to show links and commonalities between our regions.

In this step we established a communication plan which allowed us to start to communicate with artists about content. We knew where, how, and to whom we would be producing this content for, and thus chose partners with whom we would be working on specific formats.

STAGE 6:
SECOND INTERPRETATION

Richard Olˇhava,
Technical University Košice

After the communication format has been selection, the second interpretation is designed. This means that a storyline is given to the visualisation. Depending on the chosen communication format, the storyline can be either very simple or complex.

For example, images have to convey the story through one depiction only, videos usually have a linear storyline, and virtual reality applications can have even a non-linear character-driven storyline.

As mentioned through the process of creating visualisations and visual parts of exhibition it was neccessary to strictly follow the design needs of different types of visitors. In the interpretation stage there was another aspect of processing. After we set up a communication format we needed to decide which content would be best for each type of device. First of all we communicate our **3D visualisation content**.

As mentioned we made the decision not to visualise the archaeological landscape or settlement because of a lack of facts. We decided to use VR Oculus as an experience due to the atmospheric feeling of the visualisation. We decided to use a 3D rendered video to show the visitors a Przeworsk culture burial at Rankovce. The user is immediately put in the setting as a part of a group of people who are saying their last goodbye to a fallen warrior. We had to make some compromises with archaeological evidence e.g. we concluded that weapons in the graves had not been destroyed during the burial rite but likely after the ritual itself. We had to make this compromises otherwise we would have been unable to present users with a complex 3D experience. Regarding the music, rather than use reconstructed Germanic music, we opted for modern, atmospheric compositions, as we wanted that visitors will feel the importance of this ritual in such communities. This two issues were the only two neccessary compromises between art and science. All the other aspects of the visualisation including costumes, the burial ground and tools were discussed thoroughly with archaeologists.

Touchscreen Application

In the centre of our exhibition we realised that we somehow needed to present the work of archaeologists but also to display realistic images from the terrain surrounding the graves and finds. This was intended primarily for visitors with a deep interest of history, but was also planned to be shown in a popular way using , for this reason we opted to use a touch-screen application. This touchscreen device required the maximum possible cooperation between different types of professionals. To that end we employed graphic designers, programmers, an archaeologist and an architect to work in cooperation. The first part of designing app was to obtain as much informations and background documents as possible. Our aim was to design an app that would cater to two types of visitors; visitors with a deep interest in history, and visitors with a more general interest. The border between these groups is fluid, so it is easy to design an app which can help visitors to cross borders. Even when working with such a type of app we needd to work with the concept of a storyline. Our storyline was simple - the work of archaeologists at the Rankovce burial site. We used the Figma app for the general design and workflow of the app, and this product was presented to the programmers. At each step it was necessary to consult with the archaeologists. When the programmers made a beta version of the app, some final adjustments were made by the graphic designers and another consultation with the archaeologists was held. For example, in the final step we found that on each image there was certain information about the location of the site which had to be amended for the purpose of protecting the site against metal detectorists. It was also very important when designing such an app to test the app at an exhibition. After some technical issues we now know that our decisions were right and the application of archaeologist work is by far the most popular attraction for our visitors at our exhibition.

AR application

Designing such a type of app is more complicated as decisions regarding storytelling need to be taken. Augmented reality brings us numerous possibilities but it is also difficult to implement them from a technical point of view. There are effectively two types of presentations suitable for this communication format. One is to use an augmented reality app. This is the preferred option when there is a lack of space but still a desire to have augmented textual sections for objects on display. The second possibility is to develop graphic content which will be interactive, or which brings images to life. Of course one can combine both ways, and this was our mission. Because of the design process and a lack of space on our panels we used augmented reality to present more information to visitors when viewing a well-designed image of a settlement. We also employed some hidden gems - a principle well known from computer games as easter-eggs.

Using these three different types of communication formats and devices we, in this small case study, have tried to show our attempts in producing the best matching content for each device. Content and storytelling cannot be generalised and each needs to be set up differently for each occasion.

STAGE 7:

3D MODEL ADJUSTMENT: ADJUSTING OF THE 3D MODEL ACCORDING TO EXPERT DEMANDS AND CHOSEN FORMAT, AND POST-PROCESSING OF THE RENDERINGS

Marta Rakvin,
Archaeological Museum in Zagreb

Within the scope of the Danube's Archaeological eLandscapes project, the Archaeological museum in Zagreb developed digital visualisations for three sites. The three sites that were chosen (Vindja, Viškovci and Kaptol) vary greatly in the level of research and, therefore, the way in which they are presented largely depends on the dataset collected. All three sites belong to the prehistoric period. Vindija is a cave site that can be dated to the Middle (and Upper) Palaeolithic period and was populated by Neanderthals. It was excavated during the 1960s and 1970s.The Viškovci site is an Early Bronze age settlement excavated with modern methods (geophysical surveys, paleo-botanical and paleo-zoological analysis), which allowed for a more detailed presentation of the site. On the other hand, Kaptol has been systematically researched during the last 20 years, yielding a large dataset capable of telling a story about the life of the Iron Age community who inhabited it, and their surrounding landscape. Therefore, the Archaeological Museum in Zagreb opted to make three different methods of visual presentations. Applications for touchscreen monitors were developed for the Vindija and Viškovci site,[14] and an application for a virtual reality (VR) set for the Kaptol site.

For the Vindija site, the aim was to show the reconstruction of the everyday activities of a Neanderthal population inhabiting it. The focus of the storyboard was on the everyday activities of Neanderthal life such as tool making, hunting, hide working and care for the elderly. The adjustments of the visualisations were twofold. Firstly, an illustrator was commissioned to make an illustration depicting the scenes with the Neanderthals. During this phase, adjustments were made to the draft versions of the illustration by continuously communicating and instructing the illustrator how to change and adapt certain details to accord with the scientific evidence. Furthermore, in the storyboard for the final application, the visitor will be able to click on certain scenes on the illustration. By clicking on these scenes, additional info will open with texts, videos, photos and a 3D model of an object (made previously with the Agisoft software).

The second phase occurred after the application developers incorporated the illustration and additional data, such as videos, photos, 3D models of the objects and texts into the application for the touchscreen monitors. All of the photos were sent to the developers in .tiff and .jpeg formats. Texts were sent as a .docx file and videos as .mp4 files. During this phase, after the developers' initial draft, any adjustments that were made involved decisions about application design (deciding between several options given by the developers), correcting the texts, and testing the final version of the application.

[14] According to the Landscape visualisation level for all the planned landscape visualisations for Croatian sites, Kaptol has a score of 93,55 points, Viškovci the score of 76,34 and Vindija scored 35,48 points. The calculations were done in an internal study by the Archaeology group of the DAeL project.

Visualisation of the Vindija site developed for touchscreen monitors, Archaeological Museum in Zagreb.

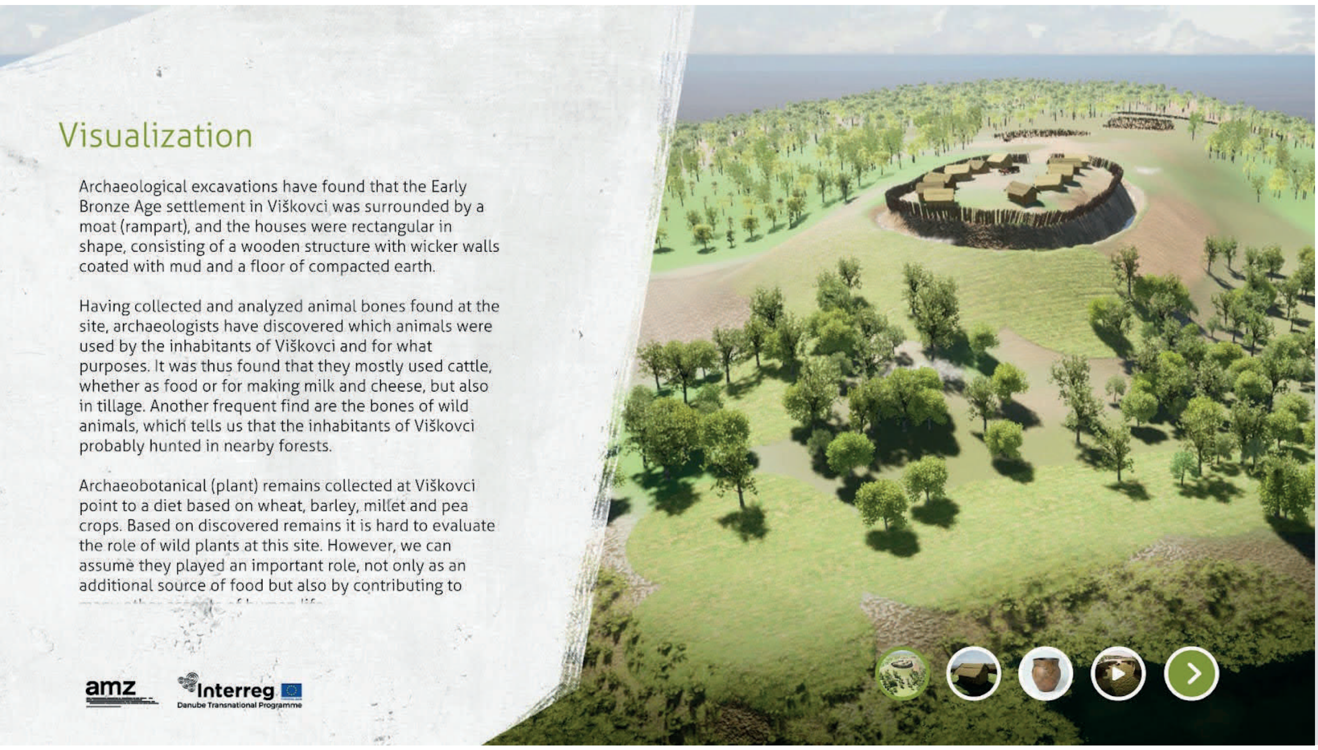
In the case of the visualisation of the Viškovci site, a similar procedure was followed. The visualisation focused on life in the settlement and activities around it. Based on the spatial data from excavations (delivered as .dwg files), geophysical survey data (delivered as .dwg files), as well as 3D models made during excavations (.psx files), an external expert made a scale digital reconstruction of the site. The settlement was reconstructed atop the 3D terrain model available on Google. During this phase, communication with the expert was vital in order to adjust all of the details, ranging from the kind of foliage growing outside the settlement to the textures used for the wood in the palisade surrounding the settlement.

Visualisation of the Viškovci site developed for touchscreen monitors, Archaeological Museum in Zagreb.

This reconstruction was then exported as a video animation in a .mp4 file and sent to the application developers, together with the photos (.jpeg and .tiff no less than 300 dpi) and texts. Following the developers' first draft, and decisions regarding the design, smaller corrections in texts were amended and the application was tested.

Both applications for Vindija and Viškovci were made with Unity software, which makes them highly compatible with different hardware and computer systems.

The museum's third visualisation was the most challenging one. The storyboard of the visualisation of the Early Iron Age site in Kaptol included several scenes depicting the warrior and his funeral. Once again, key to the successful final product was good communication with the developers, as well as sending them clear, quality data that minimised the need for corrections in the future phases. The visualisation process consisted of two steps. During the first step, an external expert made a 3D reconstruction of Tumulus IV using Agisoft and Blender software. The data for this reconstruction included spatial data from the excavations (.dwg file format), LiDAR data (.tiff) and photos. Following the archaeological interpretation of the structure of the tumulus, and after the reconstruction was initially presented, only adjustments to the textures were made. During the second step these reconstructions were sent to the developers, together with photos of the finds and texts with archaeological interpretation of the structure of the chamber and the positions of the finds. The measurements of the finds were vital. Additionally, 3D models of the pottery, that were made during the Iron Age Danube project, were also sent to the developers (Agisoft, .psx files), as was an animation of the map displaying the scope of the Iron Age Danube project with a 3D reconstruction of the settlement.



Scene from the visualisation of the Viškovci site developed for VR glasses, Archaeological Museum in Zagreb

After the first draft, it became apparent that the developers required further instructions regarding the positions and scale of certain objects in the burial chamber. Furthermore, as there are no remains of the funeral pyre, adjustments were made to the developers' initial design (one pyre for the warrior and one for the horse was changed to one pyre for both of them). With regards to the surroundings, some of the ideas, which the developers had for the settlement fortifications visible in the background, had to be removed, since there is no archaeological evidence of their existence. After the finished VR visualisation was tested, the only thing that had to be added to it was the project logo.

The level of involvement of the archaeological, technical and social aspect through the workflow, as defined in the strategy Sustainable touristic value, from digitization of archaeological heritage (Balen et al. 2021, 23) in the adjustment phase was oriented only on the technical aspect (level 3).

STAGE 8:
DISSEMINATION: FINISHED COMMUNICATION FORMATS (AND THEIR USE)

Marta Rakvin,
Archaeological Museum in Zagreb

The project partner Archaeological Museum in Zagreb developed three visualisations for the needs of the Danube's Archaeological eLandscapes project. For the Vindija and Viškovci sites, two applications were developed for use on touchscreen monitors. They run on Unity software, making them user friendly and compatible with the Windows 64-bit OS. The VR visualisation of the Kaptol site is made for Pico or Oculus VR sets.

The finished applications were made for, and will primarily be used for, the purpose of the joint partner project application and project joint exhibition Stories of the Past: Journey into Past Landscapes.

However, since the Vindija and Viškovci applications can work on most touchscreen monitors (or operated with a mouse) they can be used in many different settings in the future. Similarly, the highly transferable nature of the VR sets, makes them easy to use in many different locations, such as travelling exhibitions, various workshops, popular heritage presentations and lectures etc., thus making them a very versatile tool for heritage presentation and popularisation.

Moreover, the final applications of all three sites represent just one type of material for dissemination. As applications are composed of several 3D models, videos and 3D reconstructions, each of them can be used separately in and for presentation and popularisation purposes, which extend the possibilities of their use. This was the case during the 2022 Night of the Museums, when only individual reconstructions were presented to the public. Likewise, during an appearance on Croatian television (HRT) a selection of videos, that form parts of the applications, were broadcasted to the public.

In 2022, the Archaeological Museum in Zagreb plans to present the visualisations at the Gallery of the Archaeological Museum in Zagreb within a joint exhibition on the Hallsatt Days in Kaptol, as well as during some events in Đakovo museum (Viškovci site) and in Donja Voća (Vindija site).

The level of involvement of the archaeological, technical and social aspect through the workflow as defined in the strategy Sustainable touristic value from digitization of archaeological heritage (Balen et al. 2021, 23) in the dissemination phase was oriented largely on technical aspect (level 3), depending on the possibilities for dissemination in places different from the Archaeological Museum in Zagreb. It is also greatly influenced by the social aspect (level 3), as all dissemination activities require various engagements in the social context of the organisers of the presentations of the visualised sites.

STAGE 9:
PROJECT DOCUMENTATION

Marko Mele and Sarah Kiszter,
Universalmuseum Joanneum

Introduction

Each step an archaeologist makes in the development of digital visualisation of an archaeological site produces some kind of data, which is sometimes a major outcome of the process and other times just supporting data (meta- or paradata). All stages of the process described in the "Sustainable touristic value from the digitization of archaeological heritage" strategy have produced such data, which needs to be handled in the long term. The question is "what needs to be archived?", "what could be archived and what deleted?" and "what should be made accessible?". In this article, we will present the types of data, the storage infrastructure and the internal procedures used in the Univeralmuseum Joanneum to ensure the appropriate data documentation is used. Our museum participated in the Danube´s Archaeological eLandscapes project with the visualisation of a landscape in southern Styria (Austria) from two periods; the Iron Age and the Roman period. In the focus of the landscape visualisations, two of the most important sites were used; the Roman city of Flavia Solva and the Iron Age central settlement and tumulus cemeteries in Großklein.

Archiving infrastructure of the Universalmuseum Joanneum

The Universalmuseum Joanneum (formerly the Styrian state Museum) has collected, preserved and displayed the heritage of Styria for 211 years[15] During this long period of time the Joanneum developed sustainable and resilient storage facilities, not only for objects, but also for different kinds of data and documentation. In recent years an intensive internal process of digitization of the museum started with the development of a Strategy for the digital transformation of the Joanneum.[16]

Most of the data and documentation is stored in digital form. A major digitisation project also tackled the analogue archives of the department Archaeology&Coin cabinet.[17] For the EU-projects a separated space on the internal servers was created, which can only be accessed by project and department staff. The data on the servers is secured on several different levels.

The structure of the folders follows the basic structure of the project application. Besides the folders "Management" and "Communication" we are use three thematic "T1"-"T3" folders. The division within the folders follows the division on activities, deliverables and outputs, as defined in the application form. The data on reporting with copies of the invoices, which are internally managed by the BMD system,[18] is also printed and stored in analogue form.

Data management of Stage 1: Project planning and implementing

Data: The main data produced in this stage is a project proposal with a sound financing and time plan, supporting legal documents from partners and legal documents securing co-financing. In the project implementation

[15] https://www.museum-joanneum.at/en/about-joanneum/our-history (accessed 12.9.2022).
[16] https://www.museum-joanneum.at/das-joanneum/universalmuseum-joanneum/digitale-strategie (accessed 12.9.2022).
[17] http://www.interarch-steiermark.eu (accessed 12.9.2022).
[18] https://www.bmd.com/at/startseite (accessed 12.9.2022).

phase project reports are generated on a regular six months basis. The final output is a project proposal and reports in a Word, Excel or/and Pdf format or as in the case of the Interreg programmes in the eMS system.[19] In the process of contract signing different legal documents, like partnership agreement, partners statements, subsidy contracts etc. are produced and signed in paper and later also scanned and preserved digitally. The data is mostly digitally saved on the separated project server of the Joanneum. Additionally, a printed version of the proposal is stored in the archives of the department Archaeology&Coin cabinet.

Metadata and Paradata: For the creation of the above-mentioned output data the supporting data from all participating partners is needed. For the content of a project proposal a detailed description of the activities and infrastructure of the participating partners is created. It is mostly sent to one of the partners to adopt it to the final activity description. The budget is mostly developed in an Excel based sheet, which contains more details than the budget of the proposal. The overall budget is also finalised by one of the partners. The process of project development is quite complex and takes several months. During this time different meetings for the finalisation of different work packages are organised online and in person. The outcome of the meetings is documented in protocols or even videos. All documents are digital and saved on the separate project server of the Joanneum. The eMS system of the Interreg Danube Transnational programme documents all the steps of the projects entering in the system. It uses an assigned users system, which enables it to monitor the input of different users. All steps are documented in the timeline of the system.

Data management of Stage 2: Data acquisition

Data: For the creation of visualisations the data from more than 150 years of archaeological research in southern Styria was available. The data sources are stored in the physical and digital archives of the Universalmuseum Joanneum, published in different articles and monographic publications, and exhibited and stored in form of objects, partly displayed in the permanent exhibition of the Archaeology Museum in Graz and hamuG (Hallstattzeitliches Museum Großklein). Within the frame of the project no additional archaeological field research was conducted. We only acquired new data on finds in the form of 3D-scans of the most important objects from the Iron Age in Großklein, and 3D scans of the reconstructed Iron Age village in Großklein and the Roman period sites at Frauenberg and Wagna. Not only was data from the aforementioned Styrian sites necessary, but also analogies from other European sites. The major challenge was to select the relevant data and prepare it in an understandable way for the digital developers. The selected examples from archives and literature were also digitized if needed, so that all neccessary data, in the form of jpg and png photos, short avi videoclips and texts in docx and pdf could be stored on our project servers.

Metadata and Paradata: The vast majority of the data on the archaeological heritage and the past environment (archaeobotany, palynology…) of southern Styria is stored in the Universalmuseum Joanneum, the Federal Office for the Protection of Monuments Austria, research institutes (e.g. University Graz, Austrian Academy of Sciences, Natural History Museum Vienna…) in the Archive of Styria and diverse local and regional museums. This data contains all kinds of para- and metadata, which is mostly incorporated in the history of research parts of scientific articles. The gathered knowledge on the Iron Age is also partly online accessible via the Iron-Age-Danube database.[20] The researchers working on the visualisations were, of course using all available data, but were not

[19] www.iron-age-danube.eu (accessed 31.8.2022).
[20] www.iron-age-danube.eu (accessed 31.8.2022).

documenting and storing it separately for the purpose of the visualisation project. The knowledge of data was used merely to ease decisions on details in the visualisations.

Data management of Stage 3: First interpretation

Data: Due to the long research history, most of the data has not only been stored, but also interpreted by different researchers in the past. Similar to the raw data, different interpretations of archaeological sites, in form of jpg and png photos, short avi video clips and texts in docx and pdf were stored on our project servers. In the final step, the most plausible interpretations from the view of a responsible researcher were selected for the final use in the development of the visualisations. It is important to mention that almost no site has complete data for the interpretation, so that analogies from other sites need to be incorporated.

Metadata and Paradata: Since the development of visualisations was a participatory process organised in the form of Creative labs and hubs in our museum, single steps in the process were well documented in form of photos, videos, protocols, charts. Further selection processes and decision making was made in the internal team and documented in the form of protocols of internal meetings and drawings, which demonstrate the possible options. All the supporting documentation is stored separately from the archaeological data and interpretations.

Data management of Stage 4: 3D Model creation

Data: For the development of the visualisation, an external firm (Ilja Film) was selected in the public tender. In the first step all selected data was saved from servers to a cloud. The data was used by an illustrator, a 3D-model developer and a programmer. We offered constant support on open questions via emails, phone and online meetings. In a few months the final models of the Iron Age settlement and tumulus cemeteries and the Roman period temples, graveyard and city were provided and stored on our servers.

Metadata and Paradata: Before the final model was provided, a few development steps were needed and well-documented. On the servers of the Joanneum we saved all development stages and pilot models, which document the development process.

Data management of Stage 5: Communication Strategy

Data: The output of the process - a joint exhibition on archaeological landscapes of the Danube region -, the target groups and the communication channels were predefined in the application form of the project and detailed during the preparation meetings of the partnership. The developed visualisations were displayed on different media in the exhibition and online. A joint communication strategy, not only for the exhibition but for the whole project, was developed at the beginning of the project and adopted, if circumstances changed (COVID-19).

Metadata and Paradata: The communication of the project is a separate work package of the project. In general there were two ways of communicating, firstly from each partner on national and regional level via the institutions communication channels, and secondly the joint communication of the project conducted by the lead partner via the project communication channels (social media, project homepage, newsletters, press releases…). The joint communication in particular required quite a lot of coordination via online meetings and emails. These processes are documented and stored in our servers.

Data management of Stage 6: Second Interpretation (Storyline)

Data: In the Danube´s Archaeological eLandscapes project two kinds of storylines were created: a storyline for each visualisation, and the joint storyline for the exhibition "Stories of the past", which was shown on eight locations in the Danube region. The storyline for our visualisations was finalised in the text form and as sketches. The joint elements adopted by all partners consisted of the joint visual identity, designed by the Hungarian National Museum, and joined analogue elements incorporated in the exhibition.

Metadata and Paradata: The storyline of the visualisation of southern Styria was partly developed in the Creative Labs and Hubs and partly by the internal team with external experts. Gaming elements were also considered and incorporated. The process was documented in the form of protocols, pictures and emails. All data was stored on the servers.

Data management of Stage 7: 3D-Model Adjustment

Data: Since most of the elements of the visualisations were well-researched and prepared before the start of the 3D modelling, at this stage only minor adjustments were needed. This consisted mostly in testing of the visualisation on different media and fixing bugs. The final stored output is the visualisation in form of an app (game) installed on the final devices. The final version is also stored separately on the servers of the Joanneum and developer.

Metadata and Paradata: the supporting documentation of this stage mostly consists of emails with feedback between the researcher and the developer. The documentation is stored at the servers of the Joanneum.

Data management of Stage 8: Dissemination

Data: The exhibition "Stories of the past. Digital Journey into Lost Landscapes" was opened on 7th April 2022 in the Archaeology Museum in Graz. The visualisations were disseminated not only via the VR-glasses and touch screen in the exhibition, but also in the form of short teaser videos on social media. A press release with photos was prepared.

Metadata and Paradata: The processes for the opening and promotion of exhibitions in the Universalmuseum Joanneum are quite standardised. Besides the department of Archaeology&Coin cabinet also other departments for External relationships and Visitors. The documentation on the dissemination is stored in different departments on different servers.

Conclusion or how not to drown in the data tide

At the end the key questions to the documentation of a digitisation project are:

What needs to be archived?

What could be archived and what deleted?

What should be made accessible?

First we should look at the amount of digital data produced by an EU-project. This refers only to data stored in our servers, and not all data also stored directly on the computers of project staff, even though we have to acknowledge that that data is also a valuable meta- and paradata of the project. We also need to consider that the amount of data about the sites Großklein and Flavia Solva stored in the Joanneum and other institutions is immense and can't really be evaluated.

The first major EU-project called InterArch-Steiermark[21] produced 1,58 TB of

[21] http://www.interarch-steiermark.eu/projekte/ueber-interarch-steiermark.html (accessed 12.9.2022).

data. The small follow up project, BorderArch-Steiermark[22], conducted for only one year, also produced 148 GB of data. The projects PalaeoDiversiStyria[23] and Iron-Age-Danube[24] use 591 GB and 285 GB data space on the servers. Whilst the ongoing Danube´s Archaeological eLandscapes[25] project has already produced 214 GB of data. The five EU projects created almost 2.82 TB of data.

Considering the development of concrete visualisations mentioned above, we are storing 100 GB data on the process of creating the visualisations and 33 GB of data on the dissemination of the visualisations at the time of writing.

From the legal standpoint, all the data needs to be stored for at least five years after the end of the project in order to be able to provide information for future project controls by the financing authorities. From the museum's standpoint this data is somehow already part of the collections history and needs to be stored in the long term.

For the storage of the data the FAIR principle (findability, accessibility, interoperability and reusability) is crucial. The findability of the data is, in our case, not a major issue, since we follow the structure of the application form.Thus the application form is actually a storage plan of data and metadata for our project documentation. Since our system works on the MS Windows operating system, the integrated tools are mostly enough. The division according to work packages, deliverables and outputs helps the team members to store the documentation in the right places.

The servers with complete data on the project have a limited access given to team members and responsible staff of our museum. The data is not publicly accessible, since it has a lot of GDPR sensible data. The team members can open the data with standard preinstalled programmes. No additional authentication is needed. The persons that access and change files are not documented. Some of the data is publicly accessible via databases (www.interarch-steiermark.eu and www.iron-age-danube.eu).

The data is produced using mostly standard office tools (Word, Excel, Acrobat, different photo formats…). All the tools are updated by the museum's IT department. The long-term operability of data depends on the development of software used by the museum. The data can be transferred to different formats to be used on different systems.

10 years after the first project all data is still usable for different purposes. This is of utmost importance, since the projects are built up on each-other. We are still using most of the data. Some special data, created by specialised tools, are not fully operational anymore, but it has no impact on the outcome of the project.

Documentation of all kinds of projects, especially digital projects, is often accompanied by a high volume of different curated data, which needs to be stored on the long term. The questions posted above are therefore very relevant and need deep consideration. Not everything, especially working documents and older versions needs to be saved; this is something which was not decided when we began the projects. Therefore, the required storage for archiving could be smaller. After the end of the project there is no chance to look at all the data again and to make the selection. Therefore, a controlled and strategic approach to the documentation is an important part of the project implementation and has to be considered carefully upfront.

22 http://www.interarch-steiermark.eu/projekte/ueber-borderarch-steiermark.html (accessed 12.9.2022).
23 http://www.interarch-steiermark.eu/projekte/ueber-palaeodiversistyria.html (accessed 12.9.2022).
24 https://www.museum-joanneum.at/archaeologiemuseum-schloss-eggenberg/projekte/iron-age-danube (accessed 12.9.2022).
25 https://www.museum-joanneum.at/archaeologiemuseum-schloss-eggenberg/projekte/danubes-archaeological-elandscapes (accessed 12.9.2022).

RECOMMENDATIONS AND LESSONS LEARNED 4

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The best practice examples of the stages of the workflow from the previous chapter were analysed. In this chapter, we present a short excerpt for each stage that connects the proposed workflow from the strategies with practical instructions from Chapter 2 and practical examples from Chapter 3 in this document. We hope that in this way the reader can better understand the proposed workflow of the creation of digital visualisations of archaeological heritage and will have the opportunity to see how certain stages were tackeled by partners of the Danube's Archaeological eLandscapes project.

Stage 1:

In case study number 1: *Project Planning* a selection of archaeological (cultural heritage), technical, and social strategies from the current Interreg project Danube's Archaeological eLandscapes is presented. The goal from the start was to involve state-of-the-art AR and VR technologies. For this purpose, a wide array of project partners have been selected that cover cultural heritage, technological and management expertise. After securing the funding, several partners began working on virtual presentations of specific cultural heritage sites. For example, Universalmuseum Joanneum developed virtual presentations for two archaeological sites. Additionally, they also planned for the sustainability of all the project accrued data.

Stage 2:

The case study *Data Acquisition and the Danube Archaeological eLandscapes* examines the usage of sensitive legacy data from the times of the Nazi regime in Germany. The current research team wished to visualise the grave chamber of the Hohmichele burial mound (Baden-Württemberg, Germany) excavated in the 1930s using digital technology. After reviewing the available data, a summary of the relevant content and digitised images were forwarded to 3D artist.

Stage 3:

The case study Data Interpretation and the *Danube Archaeological eLandscapes. Hohmichele Grave VI:* Interpreting the Data shows the difficulties of interpretation when only fragmented data is available. Based on finds and analogies, the chamber and its contents were interpreted, and uncertainty about other aspects (e.g. the gender of the occupants) was disclosed.

Stage 4:

The case study *Drone-based 3D modelling of archaeological landscapes: Villa Romana Baláca* describes the setup of a drone-mounted camera for SFM-MVS approach for terrain 3D modelling. Using all the gathered images an initial dense point cloud, followed by a 3D model was created. Furthermore, the recorded archaeological features were the basis for the visualised 3D model of the architectural model of the Roman villa, which once occupied the area.

The case study 3D-modelling, a virtual reconstruction of an Iron Age hammer from the Ulaka site using Blender software, demonstrates how to model a 3D artefact based on an archaeological artefact illustration. It is a step-by-step instruction from object modelling to material assignment.

Stage 5:

In the *Communication plan for the DAeL exhibition* it was decided to set the exhibition up as a travelling exhibition instead of a permanent one. The Rankovce burial ground was used as an example to show *graves with finds, ritus, and excavation itself.* A few different types of devices (VR, AR and touchable application), modular exposition panels and few artefacts were planned.

Visitor groups were estimated at about 45 % adult visitors with a general interest in history, 40 % child and young visitors (under 15 years of age), and 15 % adult visitors with a deep interest in history.

According to the assumed interests and needs of the different visitor groups, touchscreen applications were employed, combined with a selection of 3D printed artefacts and an immersive approach via Virtual Reality application.

Graves with finds was realised using an exhibition pane with artefacts and touchscreen applications. For the presentation of Ritus a virtual atmospheric presentation through the Oculus headset, operated through head-mounted displays and hand-operated controllers and simple video was chosen. Since archaeological research of the excavation site is a work in progress, this exhibition was also an opportunity to present the ongoing landscape work of archaeologists.

Panels with greater levels of information for interested visitors and interactive content for younger visitors on touchable applications (with short, simple information) were combined to suit all visitor groups, whether they prefer traditional texts or digital technologies. For the youngest visitors, physical objects were used to maintain their attention.

Stage 6:

In the example case study *Interpretation for the DAeL exhibition*, 3D rendered videos in Oculus VR show users the burial rite of Przeworsk culture at the site of Rankovce in an immersive and atmospherically visualised way:

Visitors find themselves on site and part of a group of people who are saying their last goodbye to a fallen warrior.

At the centre of the exhibition, a touchscreen application showed the work of archaeologists at the burial ground site of Rankovce, but also realistic images of graves and finds.

Some compromises to the archaeological evidence had to be made, otherwise it would be impossible to present users with a complex 3D experience. Some information in the images had to be adapted to protect the site against metal detectorists.

Very few compromises between art and science have been made, for all other aspects of visualisation like costumes, burial ground and tools an archaeologist was consulted for scientific approval. Graphic designers, programmers, an archaeologist and an architect cooperated and consulted with each other to create this touchscreen application.

An Augmented Reality application was used to bring images to life in an interactive format and show additional texts for the objects. Despite the limited space (and for design purposes) the AR app made it possible to convey more information to visitors. Some easter eggs (hidden gems, as known from computer games) were even used.

In conclusion, in light of the three different communication formats and devices used, it should be noted that content and storytelling can not be generalised. In each isntance, the best matching content needs to be set up specifically for each device.

Stage 7:

In the example case study *3D Model Adjustment: adjusting of the 3D model* virtual visualisation was made for three Croatian archaeological sites in accordance with expert advice, slected formats, and post-processing of the renderings.

Vindija is a cave site from the Paleolithic and was populated by Neanderthals. It was excavated in the 1960s and 1970s. The format selected to present this site was an app-based clickable image portraying the daily lives of the Neanderthals who lived at the site. To this end a cave scene was chosen and an illustrator prodouced the images according to the experts' suggestions. Within the app, additional texts, images and videos were connected to the images via clickable links.

Viškovci is an Early Bronze Age settlement site, and recently researched with modern techniques. The selected format was an app-based video of the virtually visualised settlement with additional information included. The storyline choses was once again the daily lives of the residents. The 3D artist designed the village according to the interpreted data and then refined it to fit the video format and the chosen scenes.

Kaptol is an Iron Age burial site, and was extensively researched over the last 20 years. It has the largest quantity of source data. The chosen format was an immersive VR application. The storyline centred around a warrior burial. The 3D artist first designed the scene according to the source data and through several meetings with the experts. Finally, the central locations of the burial chamber and the funeral pyre were discussed in detail with the experts and accordingly adjusted accordingly.

Stage 8:

The example case study *Dissemination: finished communication formats (and their use)* discusses the computer-aided visualisation products for three Croatian archaeological sites. The products consisted of two applications for touch screen and one immersive VR application for a head-mounted display. The primary purpose was to use them for the project's joint exhibition Stories of the Past: Journey into Past Landscapes. However, due to their mobility, the museum plans to use them for various settings, including workshops or lectures. Additionally, the museum plansto reuse the content of the applications, like images, videos or 3D models, for further dissemination online, on TV or through other media.

Stage 9:

For *Project Documentation*, the documentation of the project Danube´s Archaeological eLandscapes and the visualisation of several archaeological sites for the project's exhibition by Universalmuseum Joaneumm in Graz, Austria, is presented. All the project data is saved on museum servers and meticulously organised in project-specific folders. Some files are also retained. in physical form. Metadata in each project stage mainly consists of precise naming protocols, folder organisation, and the metadata fields offered by different file formats. At some stages, additional metadata is queryable through dedicated databases. Paradata on each project stage is extensively documented through meeting protocols, photos or videos, charts, emails or notes. The data is stored according to FAIR principles.

Following the workflow:

An example on time consumed for making visualisations (based on the work of the Croatian team)

The process of making digital visualisations requires a series of steps which one has to plan ahead for. In the case of the three visualisations made by the Archaeological Museum in Zagreb, the process began with internal discussions among the members of the AMZ project team, which were followed by partner discussions and the establishment of the process of action. The first part of the process started by organising the Creative Labs&Hubs (CLH). After the preparation of the materials and the implementation of the CLH, the AMZ team developed the synopsis for the visualisations for three sites: Vindija, Viškovci and Kaptol, according to the feedback from the CLH.

With this preparatory work complete, the team furtherdeveloped some initial ideas from the CHL before approaching the external experts, and after doing so collect textual and visual data about the three sites. For the chosen sites, the external expert first developed the smaller visualisations for which the public procurement was executed. After external experts were chosen, continuous communication with them was imperative for the success of the vitalisations, especially during the testing and adjustment phase that followed. Following this phase, the procurements were made for the main visualisations. Also during this phase, special attention had to be paid to communication with the experts. A vital part of the process was testing the visualisations and making adjustments. Having finished the visualisations, the procurement process of the equipment was impletement. The visualisations were finally installed and adapted to the equipment.

WORKFLOW FOR VISUALIZATIONS DEVELOPME

PP 7 ARCHAEOLOGICAL MUSEUM

1	INTERNAL DISCUSSIONS FOLLOWING PARTNER DISCUSSIONS AND THE ESTABLISHMENT OF THE PROCESS OF ACTION
2	CREATIVE LAB&HUBS
	• Organizing the CLH
	• Preparation of materials for the CLH
	• Implementation of the CLH
	• Developing the synopsis for the visualizations for 3 sites: Vindija, Viškovci and Kaptol according to the feedback from th due to the different level of research of the three sites, different ways of presentation should be applied (for example Ka sented through VR and other two sites will be presented through touchscreens and only some parts of the sites or result it was decided that some additional steps, in form of small visualizations (like animations, illustrations, 3D modelling of final visualization for each site.
3	PREPARATORY ACTIONS FOR ALL VISUALIZATIONS
	• Development of initial idea – internal discussions based on the CLH results
	• Textual and visual data collection on the subject
3.1	VINDIJA
	1st phase: smaller visualizations: animated cave, illustration of Neanderthals in front of the cave
	Procurment
	Communication with the author
	Adjustements and checking with experts
	2nd phase: adapting the illustration for the touchscreen monitor and adding additional content to it
	Procurement
	Communication with author
	Testing and adjustements
3.2	VIŠKOVCI
	1st phase: smaller visualization: animated site with rampart and houses
	Procurement
	Communication with author
	Testing and adjustements
	2nd phase: settlement visualization for the touchscreen monitor with additional content
	Procurement
	Communication with author
	Testing and adjustements
3.3	KAPTOL
	1st phase: 3D modelling of pottery, visualization of tumulus IV
	Procurement
	Communication with author
	Testing and adjustements
	2nd phase: visualization of a burial in Kaptol for VR
	Procurement
	Communication with author
	Testing and adjustements
4	PROCUREMENT OF EQUIPMENT
5	ADAPTATION OF CONTENT TO THE EQUIPMENT
	TOTAL WORKING HOURS

ENT AND IMPLEMENTATION

IN ZAGREB

	NUMBER OF WORKING HOURS			
	Project manager	**Associate 1**	**Associate 2**	
	4	4	4	
	40	24	16	
	16	16	24	
	80	80	80	
he CLH . CLH participants noted that aptol as best research site will be pre- ts from the sites will be included). Also, exhibits) will be incorporated into the	16			
	4	4	4	
			40	
		16		
	16			
	8			
		8		
	4	1	1	
	8	8	8	
		8		
	4			
	2	1		
		8		
	4			
	2	1		
		16		
	8	4		
	16	4		
		8		
	8	4	4	
	8	8	8	
		16		
	4	4	4	
	252	**243**	**193**	**688**

Workflow of the process of visualisations development in the Archaeological Museum in Zagreb

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