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Revealing the Past, Enriching the Present and Shaping the Future

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ВИРТУАЛЬНАЯ АРХЕОЛОГИЯ

Раскрывая прошлое, обогащая настоящее и формируя будущее

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TOWARDS A VIRTUAL ART/ARCHAEOLOGY

Introduction

The term *Virtual Archaeology* was coined 30 years ago when personal computing and the first wave of digital devices and associated technologies became generally available to field archaeologists (Reilly 1991; 1992). The circumstances that led to the origin of Virtual Archaeology have been recounted elsewhere. Put briefly, Virtual Archaeology was intended for reflexive archaeological practitioners "to be a generative concept and a provocation allowing for creative and playful improvisation around the potential adoption or adaptation of any new digital technology in fieldwork; in other words to explore how new digital tools could enable, and shape, new methodological insights and interpretation, that is new practices" (Beale, Reilly 2017). Digital creativity in archaeology and cultural heritage continues to flourish, and we can still stand by these aspirations. However, in 2021, the definition and extent of this implied "archaeological" community of practice and its assumed authority seems too parochial. Moreover, the archaeological landscape is not under the sole purview of archaeologists or cultural heritage managers. Consequently, experimentation with novel modes and methods of engagement, the creation of new forms of analysis, and different ways of knowing this landscape, are also not their sole prerogative. This applies equally to Virtual Archaeology and digital creativity in the realm of cultural heritage more generally. We assert that other affirmative digitally creative conceptions of, and engagements with, artefacts, virtual archaeological landscapes and cultural heritage assemblages – in their broadest sense – are possible if we are willing to adopt other perspectives and diffract them through contrasting disciplinary points of view and approaches. In this paper we are specifically concerned with interlacing artistic and virtual archaeology practices within the realm of imaging, part of something we call *Virtual Art/Archaeology*.

We will start by outlining what we mean by adopting a diffractive Virtual Art/Archaeology approach. Then we take up a challenge recently set by Daniel Lee in which he calls for practitioners to "explore new ways of thinking about space, time and movement" (Lee 2020, 149). In an attempt to meet this challenge, we expose widespread misconceptions about all-too-familiar iconic, symbolic and indexical contemporary images (Atkin 2013) depicting archaeological landscapes, sites and assemblages in general circulation, and the role and function of the image makers. From there, we will present a series of *diffractive images* (Dawson et al. 2021) – novel and perhaps slightly disruptive experimental Virtual Art/Archaeology studies that deliberately subvert both established and new digital imaging techniques – which challenge how archaeologists, artists and others use grids, plans, maps and other images to think *through* archaeological artefacts, assemblages, sites and landscapes. We will finally put the case for more affirmative Virtual Art/Archaeology studies.

Why a Diffractive Virtual Art/Archaeology Approach?

Art/Archaeology studies have been emerging for several decades in parallel with Virtual Archaeology, and in recent years have started to build considerable momentum as a sister subdiscipline (inter alia, Shanks 1992; Dion 1999; Renfrew 2003; Wickstead 2009; Roelstraete 2014; Russell, Cochrane 2014; Bailey 2014; Bailey 2017a; Bailey 2017b; Roberts, Sterling 2017; Thomas et al. 2017; Jones, Cochrane 2018; Gheorghiu, Barth 2019; Gheorghiu 2020). Until recently, there was relatively little cross fertilisation between Virtual Archaeology and Art/Archaeology (but see Perry 2009; Wickstead 2009; Ferraby 2017; Gant, Reilly 2018; Morgan, Wright 2018; Dawson, Reilly 2019; Lee 2020). Although, the concept and purpose of Art/Archaeology is quite broad, in this paper we adopt Doug Bailey's (Bailey 2014; Bailey 2017a; Bailey 2017b) radical Art/Archaeology approach, which is to *disarticulate, repurpose and disrupt* "artefacts from their pasts and to release them into the contested dynamics of the present, through the making of new creative works, not traditionally seen as historic or archaeological in form, display or intention" (Bailey 2017b, 700). As Bailey stresses, "[r]ather than producing institutionally safe narratives conventionally certified as truth, [we] follow the lead of artists who use the past as a source of materials to be reconfigured in new ways to help people see in new ways" (Bailey 2017b, 691). In this we include archaeologists trying "to challenge their own practice-based research *creatively*" (Thomas et al. 2017, 121, original emphasis) or, put another way, those applying their creative imagination to archaeological assemblages and settings (e.g., Gheorghiu, Barth 2019; Gheorghiu 2020).

What do we mean by diffractive? We typically notice the effects of diffraction as so-called "interference patterns", commonly encountered as the overlapping concentric ripples that accompany rain landing on pooled water. When these little waves overlap they either reinforce their troughs and peaks or cancel one another out at the point of intersection. The concept of diffraction is also useful for analysing different theoretical, methodological and disciplinary practices by reading (or thinking) them through one another, like overlapping ripples, to identify those productive places "where the effects of difference appear" (Haraway 1992, 70).

In this paper, we do not only diffract archaeological and artistic *practices* through one another, we also interlace *images* of an artefact and the landscape setting in which it was discovered through one another, exploiting human and synthetic modes of cognition, and convolving ontological hybrids in the process. In so doing we evolve our own extending Virtual Art/Archaeology assemblages and emerging subversive "minoritarian" knowledge practices (see Braidotti 2018, 15). Why is a diffractive methodology necessary? Rosi Braidotti (Braidotti 2018, 15) alerts us to the prosaic character of much digital humanities research, identifying the widespread archaeological practice of 3D modelling artefacts as a classic example of an increasingly homogenous, monotonous and anemic narrative. We share Braidotti's discomfort with this "majoritarian meta-pattern", and concur with Ruth Tringham (Tringham 2016, 57) in extolling practitioners to adopt more "complex lateral thinking and playful exploratory imagination" in their research and practice. Consequently, we wish to argue for the more imaginative intra-active development and deployment of virtual techniques in archaeological situations through encounters with other disciplines such as art practice (i.e. Virtual Art/Archaeology). Diffraction shows us that the effects of difference matter. Hence, following Donna Haraway (Haraway 1992) and Karen Barad (Barad 2007), our method is a diffractive one.

An Art/Archaeology Challenge

Daniel Lee (Lee 2020, 147–148) reminds us that archaeologists have a long history of looking at, and analysing, archaeological sites and landscapes with a positivistic gaze, through differently scaled grids (in both vertical and horizontal planes), and claiming to (re)present them accurately and objectively. However, as he also notes, hidden in these apparently "static, a-political, safe, authorised images or 'tracings' of sites and landscapes" is "a large dose of subjectivity" (Ibid.). Echoing Gillings and colleagues (Gillings et al. 2020) who are also dissatisfied with these hidebound conventions, Lee (Lee 2020, 149) encourages archaeologists to "experiment with the processes and materials of archaeology and explore new ways of thinking about space, time and movement". In advocating a more experimental approach, he further proposes that "the practices, devices and processes that archaeologists use everyday (walking, mapping, surveying, writing, photography, GIS) should be *subverted* in order to explore new potential and interpretations" (Lee 2020, 155, our emphasis). In other words, he is advancing an Art/Archaeology approach, one in which he does indeed go on to explore very affirmatively in his own project. While we agree wholeheartedly with Lee that more experimental approaches should be encouraged, we also think that escaping the tyranny of the grid will be harder than many imagine. We are concerned because we detect deep genealogies of looking using grids that are embedded in, for instance, the aspect ratios of viewfinders and the rectilinear epitaxial light-sensitive crystalline lattice of the Charged Couple Device (CCD) of the digital camera, the raster arrays of pixels composing display screens, and the hardwired expectations of the firmware and software, black-boxed into all contemporary digital imaging devices (Cubitt 2014, 100–111). However, we are also hopeful that recent media studies will open up some of these black boxes and initiate new and fruitful conversations between archaeologists and artists, to retheorise digital imaging and computational photography in, and across, our respective disciplines (inter alia, Perry 2009; Cubitt 2014; Morgan, Wright 2018; Gatt 2019; May 2019; Miller 2019; Zylinska 2017; 2020; 2021; Dvořák, Parikka 2021; Likavčan, Heinicker 2021).

Deceptive Images

In parallel to the evolution of Art/Archaeology and Virtual Archaeology, the technologies of digital imaging and computational photography have evolved into a plethora of sophisticated imaging techniques and devices. Indeed, imaging technologies have become so ubiquitous that they permeate virtually every aspect of modern life in developed economies. Consequently, increasingly huge quantities of images are constantly being generated in every walk of life, discipline, industry, and government, from all over the planet. From the expansive views pouring down on us from satellites, through the continuous streams of drone and autonomous vehicle footage, endlessly repetitive selfies, and on down to the micro and nano scale landscape studies using, for example, confocal microscopes produced in laboratories, images are a relentless feature of modernity. It has become commonplace for commentators to invoke expressions of catastrophe in connection to the vast blankets of images entering digital culture, as witnessed by the widespread use of apocalyptic metaphors such as "avalanches", "deluges", "eruptions", "explosions" and "tsunamis" of images (Dvořák, Parikka 2021). In addition to the amorphous phenomenon of "masses of images", we are also witnesses to the denser, concentrated, phenomenon called "the mass image". Any internet search of a popular tourist site, such as the Kremlin, Stonehenge or Angkor Wat, will result in "an aggregate portrait tending towards a total image … extending in time (in spring; at dawn; in 1945)" (Cubitt 2021, 26). These aggregate or mass images are according to Cubitt actually complex, composite, multitemporal data visualisations. Unpacking them is an increasingly difficult challenge.

Images, it seems, are becoming unmanageable, indeed overwhelming. The question arises: who or what are these so-called "off-the-scale" (Dvořák, Parikka 2021), industrialised, scanned images aimed at? No human, or even an army of humans, could possibly look at, let alone analyse, even a small percentage of the enormous volumes of virtual "image glut" spawned each day. Instead, other machines will automatically, and increasingly autonomously, analyse these images. What might they see?

In this paper, we are not seeking truth or objectivity. We do not propose to review the technologies and theories of the mass image. (For a very good recent update see the collection of papers edited by Dvořák and Parikka (Dvořák, Parikka 2021).) Our aim here is much more modest. We simply want to interrupt the gaze of the machinic intelligences we increasingly rely on, albeit for just a moment, in order to prompt archaeologists, especially the practitioners in the field, to review the nature of modern day archaeological images. In particular, we seek to inject some diffractive and intentionally disruptive, but creative, Virtual Art/Archaeological perspectives and insights around the fluctuating nature of the materiality, and temporality of artefacts in images, and especially how the setting and location of their places of discovery are conveyed in digital images. We will explore our theme through a single artefact that Reilly discovered while fieldwalking early on in the pandemic. The artefact in question is a flint tool, usually described as a "tranchet axe" or "pick", dating from the mesolithic period. Its form and setting were recorded in situ using a digital camera, and then again in closer detail in a makeshift home studio. Afterwards this studio "shoot" was processed using the well known archaeological and cultural heritage computational photographic technique of *Reflectance Transformation Imaging* (@CHI n.d.; Historic England 2018). A single frame taken from this compiled RTI of the tranchet axe was then machinically, but aesthetically, enhanced in several studies using the perhaps less well known but very popular machine intelligence technique known as *Style Transfer* (Gatys et al. 2016; Miller 2019, chapter 7; Wang et al. 2020). We call the results of our experimentation *diffractive images*, and it is to these that we now turn our attention.

Diffractive Images

Figure 1 is not a photograph. It is an image. The two technologies are distinct and only faintly related. John May (May 2019, 50–52) sums up the distinction very neatly: "Photographs, never intrinsically calculable, remain thoroughly visual. Images, structurally calculable, are only apparently visual." The RTI of the tranchet axe that forms the basis of fig. 1–4 has more in common with a spreadsheet than a traditional photograph. Every RTI is composed of a raster grid of data made to look like a photograph. By selecting different filters available in the *RTI Viewer* application the appearance and surface properties of our virtual tranchet axe can be radically altered in order to enhance specific surface features or characteristics of interest, as seen from a fixed viewpoint but interactively relit from multiple lighting angles (fig. 1–4). Apparently different surface materialities can be generated by using, for instance, unsharp masking (fig. 1), diffuse gain (fig. 2) or specular enhancement filters (fig. 3). In addition, the calculated surface normals can be visualised using a false colour palette (fig. 4).

RTIs exhibit a very interesting form of interference pattern known by quantum field theorists as temporal diffraction patterns, in which "different times bleed through one another" (Barad 2017, 68). This happens because RTI images are derived from information extracted from multiple images taken of a stationary subject from a stationary viewpoint at *different times*. The RTI variously rendered in fig. 1–4 was developed using 48 separate images taken one after the other in some particular order in an ad hoc home office studio set. The quality is not necessarily the best, but that is not really a point of concern here. Each contributing image is clearly distinguished from each other by the different highlights and shadows that are produced by projecting light onto the subject from unique but known (or knowable) directions. Using the *RTI Builder* software, the lighting information from each image is synthesised into a mathematical model of the subject's geometry and surface properties, and then encoded in such a way that each constituent pixel of the compiled RTI can accurately model how light behaves at the specific point of the surface it is depicting. This allows users of the *RTIViewer* application to virtually re-light and investigate their models interactively from a fixed viewpoint in extremely fine detail in any number of different lighting sequences. Notice the shadows that fringe the tranchet axe (especially in fig. 2). They show the superposition, or entanglement, of different light waves recorded in the different images – taken at different times – diffracting through each other. This temporal diffraction pattern is a tell-tale sign that a not quite "monstrous cyborg" (Haraway 1991), something we might call a temporal frankenstein, has been "enslaved" in the RTI (pace Cubitt 2014, 270). We will return to the importance of cyborgs later.

Our next step was to explore some effects of diffracting machine intelligence through our already diffractive RTI. The diffuse gain rendering of the RTI shown in fig. 2 was selected for further experimentation in our Virtual Art/Archaeology collaboration because of its very pronounced temporal diffraction pattern of overlapping shadows.

The Virtual Art/Archaeology study shown in fig. 5 encapsulates the effect of diffracting our RTI of the tranchet axe with machinic cognition. It could be categorised as an example of *AI Art* (see Miller 2019; Zylinska 2021). It was created by applying the computer vision technique known as "Style Transfer", a technology readily available via the internet, to our RTI. Without going into detail, Style Transfer is a mode of artificial intelligence that relies on sophisticated "neural algorithms of artistic style" (Gatys et al. 2016) using a very deep convolved neural network (Simonyan, Zisserman, 2015) to extract the *style* of one image and transfer it onto the *content* of another (see Miller 2019, chapters 7–12; Wang et al. 2020). The outcome is another form of diffractive image that interlaces different styles and subjects through a machinic way of seeing. In this instance, it also interlaces vastly different scales of perception. Here, our "content image" was the compiled RTI frame shown in fig. 2, featuring the strongly defined fringe of interlaced shadows that materialise the temporal diffraction pattern referred to earlier. The applied style image is a creative commons Nomarski Differential Interference Contrast microscopy rendering of a partially etched silicon integrated circuit wafer (Richstraka 1979). The result of this diffraction experiment is *Silicon Alchemy II*, which is a radical departure from standard archaeological representations of flint or chert (i.e. silica) objects (e.g., Raczynski-Henk 2017; Gatt 2019). It is oneof a series of diffractive digital studies exploring the recursive intra-action of light, shadows, silica/silicon and artificial neurons (e.g. Reilly 2020).

Fig. 1
RTI of tranchet axe using diffuse unsharp masking filter. Image: P. Reilly & I. Dawson

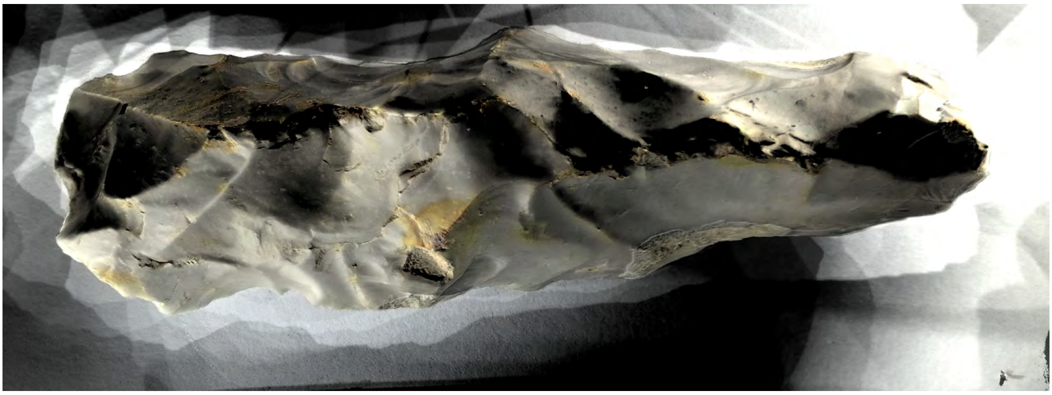

Fig. 2
RTI of tranchet axe using diffuse gain filter. Image: P. Reilly & I. Dawson

Fig. 3
RTI of tranchet axe using specular enhancement filter. Image: P. Reilly & I. Dawson

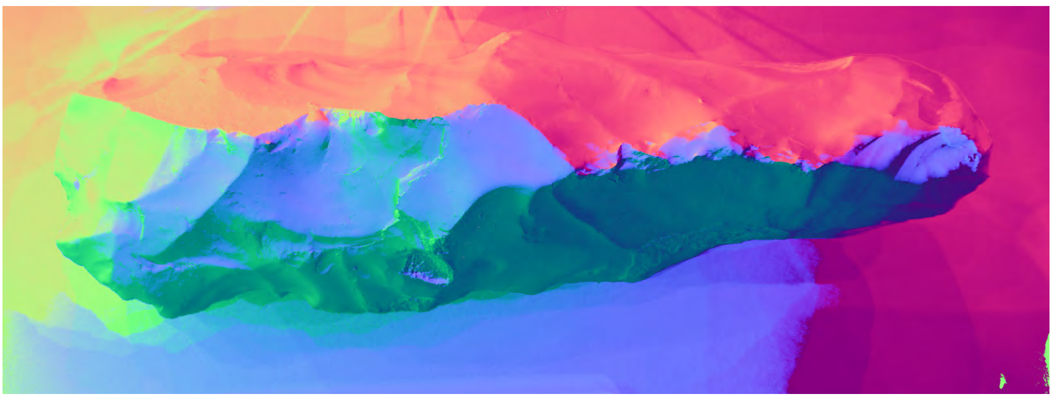

Fig. 4
RTI of tranchet axe showing colour-coded surface normals. Image: P. Reilly & I. Dawson

In this study the archaeologist's usual analytical gaze upon the "impact scars" that shaped the flint tool through the RTI image is radically disrupted when it is convolved through the machinic gaze of a *style transfer* deep neural network (CNN). The outcome of this exercise is a diffractive image in which the RTI multi-lit flint artefact, including its spacetimemattering *compound shadows*, is seemingly transmuted and rematerialised as backlit stained glass. The artefact is rendered recognisable as a pluritemporal, multiscaler phenomenon by an eclectic posthuman cognitive assemblage. However, this cyborgic *perspectiva naturalis* (Cubitt 2014, 210) is just one rendering of a digital description actually made to be projected inwards in order for the internal "(re)viewer", that is the software programme, to be able to perceive and engage with it. This diffractive image reveals how the computer has become engaged in the construction of visibility, and how the silica "eye" of the software programme is active in its vision, in what it sees and how it displays its nature.

Our next Virtual Art/Archaeology study, *Diffractive Tranchet Axe Landscape 2021*, shown in fig. 6, is the result of diffracting our signature RTI style image of the human-held mesolithic tranchet axe with the content of a satellite image covering several square kilometres of the landscape in which the artefact was found. It was produced using the same Style Transfer algorithm and CNN we employed earlier. Once again, hugely different scales of perception, and notions of near and far, are being interwoven.

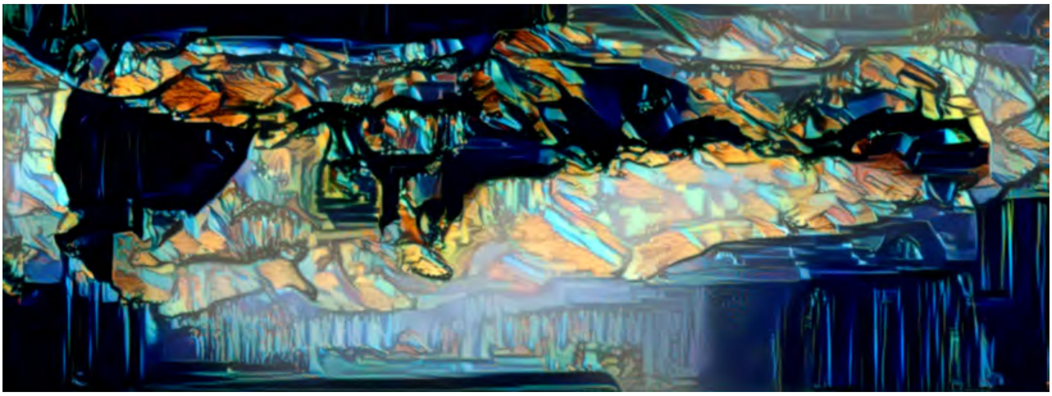

Fig. 5
Silicon Alchemy II. Image: P. Reilly & I. Dawson

Fig. 6
Diffractive Tranchet Axe Landscape 2021. Image: P. Reilly & I. Dawson

The pluritemporal palimpsests (Olivier 2011) of maculae exposed in the ploughed fields (i.e. soil-based auto-expressions of buried features) are now rendered on the surface of the tranchet axe; they reference and relocate other traces of archaeology from the wider landscape of discovery. Ironically, perhaps, maculae are increasingly being detected automatically in remotely-sensed data using similar deep learning techniques based on CNNs (for a recent summary of the state of the art automated remote sensing in archaeology see Davis 2021). Here, however, just one area of such archaeologically autographic images (Offenhuber 2020), or self expressing "planetary diagrams" (Likavčan, Heinicker 2021), was framed by a human and then interlaced with the multi-lit topography of the hand-holdable mesolithic flint artefact. In other words, we convolved the RTI of the tranchet axe with the satellite image of the landscape setting of its place of discovery, as remotely-sensed through the gaze of a "space archaeology" cyborg (e.g. Parcak 2009; 2019). As John Beck puts it in connection with other abstract art aerial perspectives, this vertically distanced image sends "messages as documentary and messages as art, one interrupting the other" (Beck 2013, 62). The result can be described as "a posthuman diffractive image". By which we mean that human and machinic vision, human and much-bigger-than human scales, contemporary and ancient temporal ripples, and art and archaeological practices, have been diffracted through one another to produce a totally new conception of the place, setting and scale of the artefact and its contemporary landscape.

For our final Virtual Art/Archaeology study, titled *Track and Trace III* (fig. 7), we pick up on Daniel Lee's observation that archaeologists are "obsessed" with viewing the archaeological landscape through "archaeo-mental maps" structured by scaled grids (Lee 2020). Again, we also experiment with the notion of location, setting, and time. Like all the other studies presented in this paper, *Track and Trace III* was created during the ongoing global coronavirus pandemic, in 2021. Throughout the pandemic many governments implemented so-called *track and trace* systems to help control the spread of COVID-19. In connection to this global tragedy the QR-code has become a zeitgeist of the pandemic. In Britain, where they are placed prominently in every shop, cafe, business and hospital, they are used to identify potentially contagious events, retrospectively, by identifying where and when an infected person came into contact with other people. They are also an example of what Joanna Zylinska calls "nonhuman photography", meaning that they are not *of*, *by* or *for* humans (Zylinska 2017, 5, original emphasis). QR-codes are machine readable optical labels that can describe the thing or place to which they are attached.

Fig. 7
Track and Trace III. Image: P. Reilly & I. Dawson

They present themselves as a set of black squares arranged in a square grid on a white background, and they are "read" by imaging devices such as a digital camera. In other circumstances, compliance to the processes of "track and trace" allows organisations to connect individual objects, or assemblages, to inventories and to track their movements. Location, place, time, duration, provenance, and the use of grids are central concerns to *Track and Trace III*. As it happened, the find-spot of this particular tranchet axe had been recorded using the what3words location finder application. *What3words* divides the world into three-metre squares and gives each square on this global grid a unique three-word address. In this study, the *what3words* location triplet of our findspot has been rendered as a QR-code (incidentally, using another readily available online application). This QR-code, declaring the unique *what3words* location triplet of our findspot, was then style transferred onto the same compiled RTI image used in fig. 2.

Track and Trace III is therefore a study in the recursive interplay of grids laid out at different scales and times, exploring different notions of provenance at different levels of granularity and expression. Although eroded through convolution, both artefact and grid somehow persist.

Discussion

Images are never "innocent"; they carry genealogies of seeing (Moser, Smiles 2005; Cubitt 2014). Increasingly, we are witnessing the automation of archaeological digital imaging and the widespread production of terrestrial, aerial and satellite orthographic, multi- and hyper-spectral, images. In other words, our cyborg collaborators are generating images with no perspective distortions, manufactured from a digital mosaic of digitally manipulated component images that are stitched together. They present a synthetic view that no human could experience directly. It becomes clear that the role of the archaeologist in generating these images has been reduced to that of a mere "functionary" (see Flusser 2011), someone who Sean Cubitt (Cubitt 2014, 270) sees as "enslaved" to, by, and in the media technologies they use, like the "writer who writes for his pen" (Virilio 1994, 76). Today, at least as far as terrestrial imaging goes, that "someone" is quite often an archaeologist who is trained (or programmed) to compose an overlapping set of views – that, incidentally, conform to millions of other similar excavation plan and section images that have been taken by other field archaeologists all over the world for generations – and then press the appropriate button (Lucas 2012, 242). Job done?

In the same year that Virtual Archaeology emerged as an idea in print, Donna Haraway famously remarked that "We are all chimeras, theorized and fabricated hybrids of machine and organism; in short, we are cyborgs" (Haraway 1991, 150). As the ever growing glut of images that archaeologists and others produce needing to be analysed grows, the balance between the proportion that is delegated to a human archaeologist versus that of their machinic collaborators shifts considerably. Consequently, cyborgs emerging now are increasingly a blend of majorian artificial intelligence techniques and a minorian of specialised archaeological technocrats. One dystopian corollary might be that of a growing cohort of archaeological functionaries whose majorian methodology and research questions have become enslaved to the techno monsters that Haraway alerted us to 30 years ago (Haraway 1991; 1992). Indeed, our diffractive Virtual Art/Archaeology approach may be regarded as the monstrous hybrid spawn of nonhuman, posthuman, post-photographic cyborgs. We take the view that our cyborgic Virtual Art/Archaeology studies have archaeological, artistic, humanistic and scientific merit. We are in accord with Isto Huvila who suggests that a monstrous perspective may actually be critically productive in the analysis of visualisation and social information technologies in general. As Huvila argues convincingly:

"Building on Haraway, the fact that photorealistic visualizations or other social information technologies (combining human and machine in one) unfold as monstrous cyborgs means that they have a potential to bring forth a range of new ways of interacting and not interacting with information (i.e., information work practices and/or information literacies) better and worse. To understand their potential and related risks, it is important to delve into the complete entanglement of diverse programmes they are driving and driven by, instead of falling back to a dualism of one programme and its anti-programme." (Huvila 2020, 54)

It is the contention of this paper that a Virtual Art/Archaeology approach is another valid way of keeping both the technocratic and machinic gaze of our latter day "uber-archaeologists" (Wickstead 2009) to critical account. By taking a miniscule sample of the masses of available images, or condensed mass images, and then subverting them, including their underpinning methods and philosophical basis, we have another transdisciplinary way of holding at least some archaeological cyborgs, and their processes, to account. We suggest that a Virtual Art/Archaeology approach both encourages and acknowledges the importance of creative researchers in search of novel, diffractively critical, ways of perceiving, understanding and knowing a new version of the "archaeological record".

In this paper we attempted to critically analyse widely-used digital imaging techniques by adopting a diffractive Virtual Art/Archaeology approach in order to deliberately dislocate, disarticulate, repurpose and, ultimately, disrupt the normative narratives they habitually evince. Along the way, we have diffracted art and archaeological practices, human and nonhuman cognition, different times, contrasting modes of (re)presenting places and settings, near and far, and other radically opposed scales of perception, to expose the effects of difference and their different affects. Specifically, we have exposed for critical review those pervasive grids, meshes and lattices that lay hidden inside archaeological black boxes but continue to structure archaeological practice.

Clearly, diffractive images call for new and previously unfamiliar modes of viewing and interpretation. However, as Mark Gillings, Piraye Hacıgüzeller and Gary Lock argue: "There should be no limit to what is deemed mappable" (Gillings et al. 2020, 12) or, to extend their insight, "imagable". The Virtual Art/Archaeology studies presented in this paper should not be thought of as some kind of static record of an object, place or event. Rather, we offer them as provocations. We hope that more practitioners embrace the idea of developing other Virtual Art/Archaeology studies that productively unpack, disassemble and reassemble other digital practices in order to provide new creative, and affirmatively critical ways of looking at, and novel ways of presenting, archaeology positively.

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РУССКИЕ ГОРИЗОНТЫ «ТЕРРИТОРИИ»: ОПЫТ ОРГАНИЗАЦИИ ВИРТУАЛЬНОЙ ВЫСТАВКИ ПО РЕЗУЛЬТАТАМ РАБОТ ГИЖИГИНСКОЙ АРХЕОЛОГИЧЕСКОЙ ЭКСПЕДИЦИИ

Введение

История Гижигинска – первого города на территории современной Магаданской области – связана с освоением территорий в Сибири и на Дальнем Востоке России в XVII–XVIII вв. На основе архивных материалов и исторических описаний восстановлены события, связанные с открытием р. Гижиги в XVII в. М. Стадухиным (Бурыкин 2015), с функционированием Гижигинской крепости (Вдовин 1995). Гижигинск рассматривался в контексте изучения освоения Северо-Востока России (Назарова 2015); выделены этапы в его истории (Конь, Понкратова 2019); ставился вопрос о необходимости его включения в Перечень выявленных объектов культурного наследия Магаданской области (Лебедева, Понкратова, Волков 2020). Особое внимание к Гижигинску было привлечено со стороны общественности г. Магадана и Магаданской области. О нём как о «забытом городе» на Севере Дальнего Востока России писали в социальных сетях (Афанасьев 2017); с губернатором Магаданской области С. К. Носовым обсуждался вопрос о необходимости проведения его специальных исследований (Пресс-релиз 2019). Совместно с правительством Магаданской области (М. С. Бродкин), областным отделением «РГО» (А. В. Нестерович) и Северо-Восточным государственным университетом (далее – СВГУ) инициирован и при поддержке И. Б. Донцова и ВОО «РГО» (грант по договору № 13/2020-Р) частично реализован историко-просветительский проект «Гижигинская археологическая экспедиция» (далее – проект) (Ponkratova, Lebedeva 2020). В рамках проекта местонахождение Гижигинска предварительно изучалось в 2019 г., и как археологический объект впервые он обследован в 2020 г. Гижигинской археологической экспедицией (далее – экспедиция) под руководством С. В. Батаршева (открытый лист № 1555-2020) и И. Ю. Понкратовой. Полученные данные позволили восстановить особенности топографии и функционирования объекта и стали основой виртуальной выставки «Гижигинская археологическая экспедиция: открытия 2019–2020 гг.» (далее – выставка).

Виртуальная выставка «Гижигинская археологическая экспедиция: открытия 2019–2020 гг.»

III Всероссийская научно-практическая конференция «Университеты России в диалоге со временем», посвящённая 60-летию СВГУ, проводилась 19 ноября 2020 г.

в онлайн-формате в условиях ограничения массовых мероприятий в связи с пандемией COVID-19. В разделе конференции на официальном сайте СВГУ была представлена выставка (рис. 1), созданная при помощи системы подготовки презентаций Power Point. Информация о выставке размещалась в социальных сетях. Она стала объектом обсуждения не только участников конференции, но и лиц, интересующихся историей родного края, краеведов, историков, археологов.

Цель выставки – продемонстрировать результаты, полученные в условиях полевых исследований ОКН «Город Гижигинск» в Северо-Эвенском районе Магаданской области. В основе экспозиции лежит научная концепция, определяющая актуальность исследования объекта (рис. 2), цели и задачи проекта, назначение которого – изучение культурно-исторического наследия Магаданской области, воспитание у молодёжи патриотического отношения к малой родине и её истории, включение территории в сферу туризма.

В формате слайдов на выставке показаны карты места расположения (рис. 3, А, Б), топографические инструментальные планы объекта с прилегающей местностью на основе ортофотоплана, выполненного по данным БПЛА DJI Phantom 4 Pro при помощи программного комплекса Photo Scan.

Полученные данные позволили наглядно продемонстрировать особенности рельефа и функционально-планировочное зонирование территории объекта (рис. 3, В). Были зафиксированы остатки 38 построек в виде земляных возвышений различной в плане формы (рис. 4, А). Основная часть построек расположена на поверхности первой надпойменной террасы; здесь находится селитебная часть города и кладбище. После расчистки от современной растительности одной из построек (рис. 4, Б) удалось определить её размеры и контуры с выступом (вероятно, остатки пристройки

Рис. 1
Виртуальная выставка «Гижигинская археологическая экспедиция: открытия 2019–2020 гг.»: титульный лист.
Изображения С. В. Батаршева, дизайн И. Ю. Понкратовой

или веранды). В центральной части объекта выявлен вход в селитебную зону в виде ложбины с оплывшими бортами (рис. 4, В). С северной и восточной сторон территория объекта ограничена каналами, предназначенными для защиты города от тундровых пожаров и отведения избытка дождевой и талой воды (рис. 4, Г).

Город Гижигинск – памятник землепроходческого движения
и русского освоения Севера Дальнего Востока России в XVII–XIX вв.

Рис. 2

Виртуальная выставка «Гижигинская археологическая экспедиция:
открытия 2019–2020 гг.»: актуальность исследования.
Изображения С. В. Батаршева, дизайн И. Ю. Понкратовой

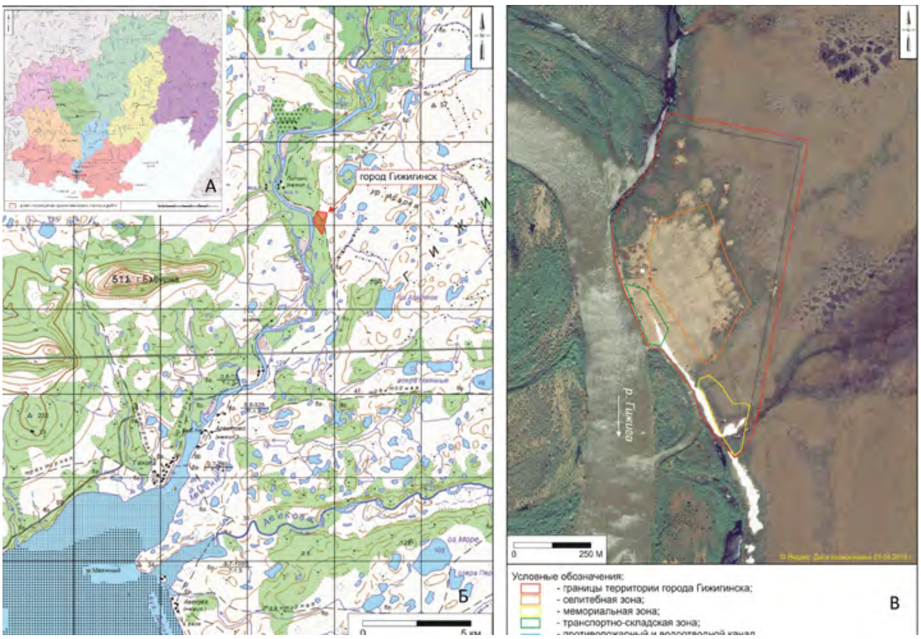

Рис. 3

ОКН «Город Гижигинск» (Магаданская область, Северо-Эвенский городской округ):
А, Б – карта района исследования; В – схема функционально-планировочного
зонирования территории. Изображения С. В. Батаршева

Рис. 4

ОКН «Город Гижигинск» (Магаданская область, Северо-Эвенский городской округ): А – топографический инструментальный план ОКН «Город Гижигинск»; Б – остатки постройки № 24 после расчистки от современной растительности (вид с севера); В – вход в селитебную зону (вид с запада; аэрофотосъемка); Г – противопожарный и водоотводной канал в восточной части ОКН (вид с северо-востока; аэрофотосъемка). Изображения С. В. Батаршева

Мемориальная зона находится на небольшом удалении к югу от селитебной зоны. Она расположена на поверхности, краю и склонах первой надпойменной террасы (рис. 5, А). Были обнаружены остатки девяти могил, на которых сохранились фрагменты деревянных крестов и каменных надгробий с металлическими оградами К. Т. Пржевалинского (рис. 5, Б, В) и Н. П. Брагина (рис. 5, Д, Е); от одной могилы осталась металлическая надгробная плита купца П. П. Брагина (рис. 5, Г).

В разведочном раскопе площадью 9 м^2 выявлены остатки деревянной постройки, элементы которой залегали во всех почвенных горизонтах, и условно разделены на остатки кровли, дверной коробки, стены, пола, балок перекрытия пола, печи. Фотографии и рисунки элементов конструкции демонстрировались на выставке (рис. 6, А–В).

Обнаруженные в раскопе артефакты представлены на фотографиях. Это предметы быта и торговли, религиозная атрибутика, инструменты, посуда, украшения, игрушки, монеты и пр. (рис. 8). Наибольший интерес у зрителя вызвали киотные кресты (рис. 7, А), позолоченная фигурка Богородицы (часть скульптурной композиции «Распятие с предстоящими») (рис. 7, Б), фрагмент серебряного налобного оклада (корона) иконы (рис. 7, В).

Рис. 5

ОКН «Город Гижигинск» (Магаданская область, Северо-Эвенский городской округ): А – мемориальная зона (кладбище) (вид с юго-запада; аэрофотосъемка); Б – захоронение, грунтовая могила К. Т. Пржевалинского, каменная могильная стела (вид с востока); В – захоронение, грунтовая могила К. Т. Пржевалинского, остатки могильных плиты и стелы (вид с севера); Г – захоронение, металлическая плита с могилы П. П. Брагина (вид с запада); Д – захоронение, грунтовая могила Н. П. Брагина, часть могильной металлической ограды (вид с юго-востока); Е – захоронение, грунтовая могила Н. П. Брагина, часть каменного обелиска с эпитафией на английском языке (вид с юго-востока). Изображения С. В. Батаршева

Не меньший интерес был проявлен к монетам, которые особенно важны для установления хронологических границ функционирования города (рис. 8, А, Б). Самой ранней по дате чеканки стала монета, относящаяся к середине XIX в. (20 копеек 1879 г.), самыми поздними – монеты 1938 г. (достоинством 1 и 2 копейки). Были найдены монеты, отчеканенные как во время существования Российской империи (1909 г.), так и в советское время – в 1924, 1930, 1931, 1936 гг. Единичной является находка японской монеты «Куань-Юн тун бао» с характерным для восточных монет квадратным отверстием в центре. Выпуск таких монет осуществлялся с 1626 по 1860 г.

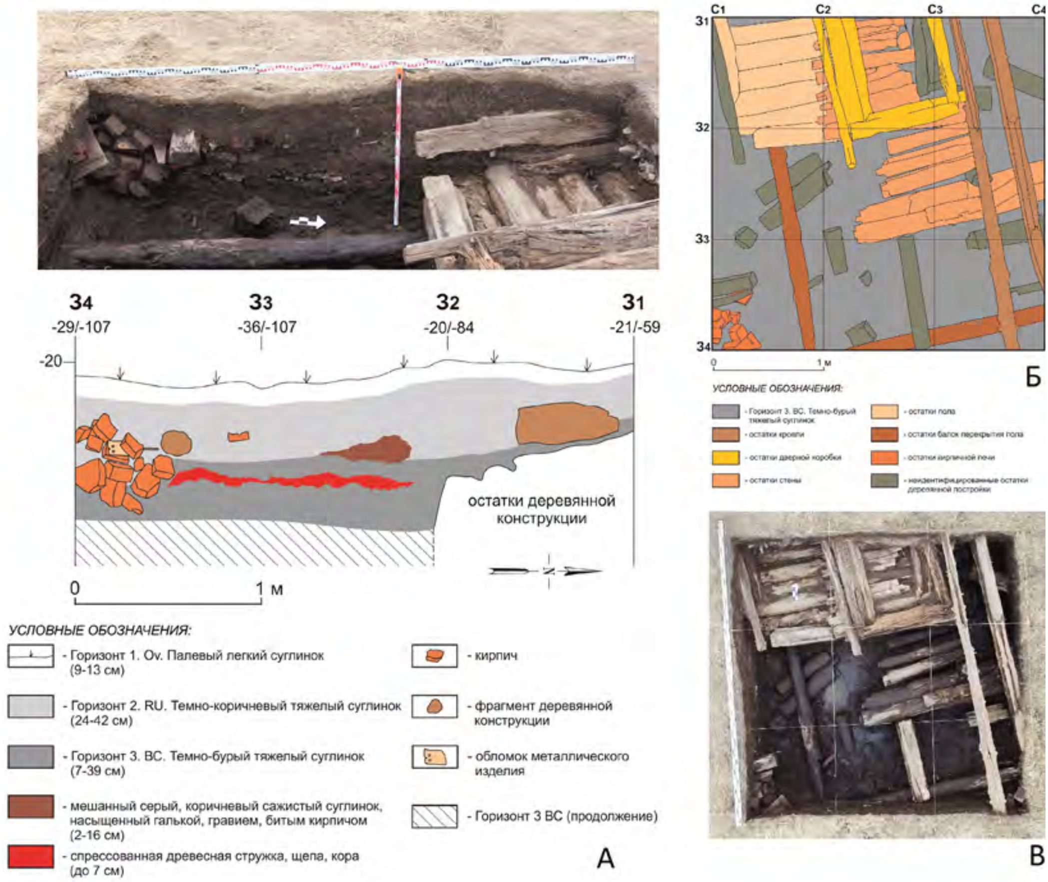

Рис. 6

ОКН «Город Гижигинск» (Магаданская область, Северо-Эвенский городской округ): А – раскоп, разрез западной стенки (вид с востока); Б – раскоп, элементы конструкции деревянной постройки (рисунок); В – раскоп, элементы конструкции деревянной постройки (фото). Изображения С. В. Батаршева

Значительную долю находок составляют инструменты: ремесленные сельскохозяйственные, бытовые. Среди них топоры, лопаты, ножи, полотна кос, зубила, молотки, плотницкий бурав, детали сенокосилки, а также абразивы для заточки и доводки орудий (см., например: рис. 8, В, Д).

Отдельную группу представляют изделия из бивня мамонта – вырезанная небольшая фигурка человека и крупный фрагмент бивня с подтеской на одном конце (см., например: рис. 8, Г). Следует отметить и находку детской игрушки – деревянную фигурку зайца (рис. 8, Е).

К категории индивидуально-бытовых находок отнесены женские гребни, расчёски, бисер и бусины, фрагменты и стеклянные пробки от парфюмерных флаконов, металлические ножницы, мундштуки, перочинный нож, опасная бритва, кольцо, пуговицы, крышки от карманных часов или пудрениц, зубные щетки, металлические пряжки и пр. (см., например: рис. 8, Ж–И). Зафиксированы в большом количестве фрагменты фарфоровой, фаянсовой и стеклянной посуды (банки, бутылки и их фрагменты) (например, рис. 8, К).

Рис. 7
Религиозные артефакты ОКН «Город Гижигинск»: А – киотные кресты;
Б – фигурка Богородицы (часть скульптурной композиции «Распятие с предстоящими»);
В – фрагмент серебряного налобного оклада (корона) иконы

Поскольку представленные на выставке материалы могут вызвать ажиотаж среди «чёрных копателей», на заключительных слайдах организаторами выставки дана информация о включении ОКН «Город Гижигинск» в Перечень выявленных объектов культурного наследия Магаданской области и запрещении раскопок на территории без специального разрешения.

Заключение

В целом опыт организации выставки позволяет сделать вывод о том, что осуществление виртуальных экспозиций по результатам полевых работ проведённых в текущем году археологических экспедиций не только возможно, но и необходимо. С одной стороны, изображения обнаруженных материалов доступны большому числу зрителей, с другой – визуализируются научным сообществом и сразу становятся предметом дискуссии, позволяют наметить направления их научного изучения на этапе лабораторных анализов и интерпретаций.

При организации виртуальной выставки очень важно наличие качественных исходных материалов – полученных с помощью ортофотосъёмки топографических инструментальных планов объекта, обработанные в редакторах фотографий артефактов и пр., что возможно только при слаженной работе специалистов разного профиля. Созданная в формате презентации Power Point выставка может стать макетом для организации стационарной и выездной выставок музея, а её апробация в виртуальном пространстве позволит выявить недостатки и, наоборот, отметить наиболее эффектные для зрительского восприятия аспекты.

Рис. 8

Артефакты, обнаруженные при исследовании ОКН «Город Гижигинск»: А, Б – монеты; В – металлический топор; Г – фигурка человека из бивня мамонта; Д – полоса (клинок) металлического ножа; Е – деревянная фигурка зайца; Ж – пластмассовый гребень; З – бусины и стеклянный бисер; И – металлическая крышка пудреницы или корпуса карманных часов; К – фрагменты фаянсовой посуды. Изображения Н. А. Дорофеевой

Кроме того, данный формат не требует особых навыков компьютерной грамотности и позволяет оперативно, не дожидаясь публикации научных статей или организации стационарной экспозиции, представить результаты сразу после полевого сезона археологической экспедиции.

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RETHINKING THE ANALOGUE – FROM VIRTUAL ARCHAEOLOGY TO A DIGITAL EXHIBITION

Introduction

In 1993, workers discovered a mummified human head during exploitation in the salt mine of Chehrābād, Province of Zanjān, Iran (Vatandoust 1998). This find marks the beginning of more than 20 years of international and interdisciplinary research. The mummified head dates to Sassanian times and is known to the world today as "Salt Man 1". The salt extraction in Chehrābād continued until 2009 and led to the discovery of further mummified human remains, which were, in accordance to the first find, named "Salt Men of Zanjān". These salt mummies as well as the site are a unique cultural heritage for humankind.

In 2004, archaeologists made an exceptional discovery during a rescue excavation. This find, the mummy of a 15 to 16-year-old youth, is – to date – the best-preserved salt mummy known worldwide (Aali 2005). In 2007 an international research project started, co-headed by the German Mining Museum Bochum and the Zanjān Saltman and Archaeological Museum. All these efforts led to the halt of the commercial exploitation of the salt mine in 2009. Subsequently, the salt mine was declared a cultural heritage site (Aali et al. 2012). In multiple excavation campaigns not only the salt mine itself, but also its surrounding area were studied thoroughly. The results of these joint efforts were published in two monographs (Aali, Stöllner 2015; Stöllner, Aali, Bagherpour Kashani 2020) and various further articles (e.g. Aali et al. 2012; Öhrström et al. 2016; Pollard et al. 2008; Ramaroli et al. 2010; Vahdati Nasab et al. 2019).

Digital Archaeology at the Zanjān Excavation

Beginning with the 2016 campaign, digital documentation methods were used increasingly, both in the field and in the offices. In past campaigns, GIS mapping and interpretation were already employed, but thanks to technological advances new methods could be applied in this project, especially photogrammetry-based 3D documentation and the usage of unmanned aerial vehicles (UAVs) (fig. 1).

3D documentation of ancient mines is a desideratum pursued for more than twenty years (Steffens, Schimerl 2021). Only in recent years, the technological progress allowed processing the highly irregular geometry encountered in ancient mines for larger datasets, thus enabling the researchers to continuously 3D document an excavation and process the captured raw data in the field. Though many different methods of 3D documentation were tested

Fig. 1
The UAV flights were also used for an in-depth study
of different photo acquisition apps. Photo: N. Bagherpour Kashani

in underground mining sites, none have proven as efficient as image-based modelling, often also referred to – as pars pro toto – as structure from motion (SfM). Besides allowing for a highly mobile and flexible documentation, one of the key advantages of a photogrammetry-based workflow is the nature of the raw data – photographs – itself, as the hundreds of photos allow generating a highly detailed texture. In contrast to image-based modelling, terrestrial laser scanning (TLS) has proven to be quite inefficient in the oftentimes jagged and narrow cavities found in mines of archaeological interest. The texture captured by TLS is, in comparison to a texture generated with image-based modelling, also lacking in quality and potential resolution. While the colour information is oftentimes of interest in an archaeological context, it is even more so in mining archaeology, as tiniest traces of ore veins, soot, or tool marks too shallow to be present in the geometry of a 3D model can help interpreting the mining sites.

The salt mine of Chehrābād is nowadays an opencast mine covered by a man-made roof for protection of the archaeological site against the forces of nature. The encountered geometry reflects the site's nature of an underground mine in Achaemenid and Sassanid times. Therefore, applying a photogrammetry-based 3D documentation deemed a natural decision. From 2016 onwards a 3D model of every excavated layer was photographed and processed, leading to a very rich dataset allowing to interpret the stratigraphy of the site, combined with the detailed Harris matrix, in a four-dimensional way. The detailed documentation of the tool traces preserved in the rock salt allows to study the mining techniques applied in Achaemenid and Sassanid times elaborately as well as to compare them to tool traces created by the researchers in archaeological experiments. By comparing the datasets, it could be proven that the technique used by the researchers resembled that of the Sassanian miners – at least regarding the traces left by the exploitation process.

Combined with extensive geoarchaeological core drillings and geoelectrical surveys, the generation of a landscape model of the salt mine and its surrounding area was a crucial step to get a deeper understanding of the interlinkage between the salt deposit, its exploitation, and the land usage around the Douzlākh. The first efforts of documenting the landscape with a DJI UAV started in 2016. The promising outcomes led to two further documentation campaigns finally resulting in a highly detailed landscape model covering about 4.5 square kilometres with a ground resolution of about two square centimetres per pixel. A landscape model of this size and ground resolution is unique in Near Eastern salt mining archaeology (fig. 2).

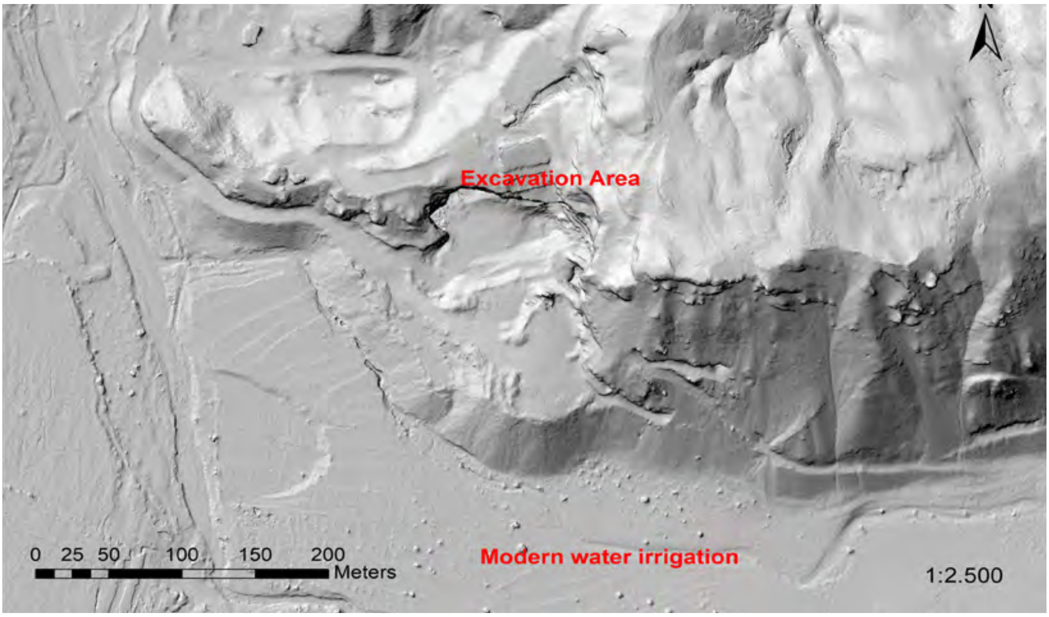
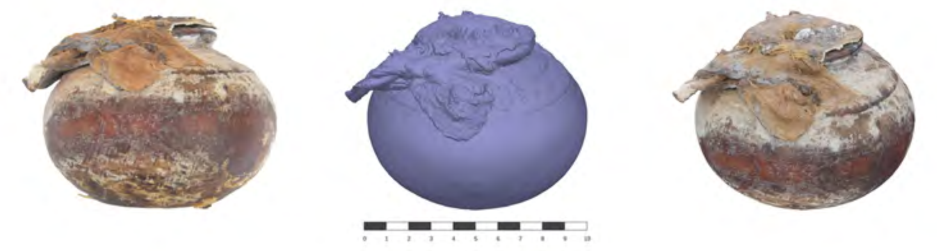


Fig. 2
Hillshade view of the landscape model showing the terracing used for water irrigation in modern times. Screenshot: N. Schimerl, German Mining Museum Bochum

Fig. 3
Avatar of Salt Man 4 with digitally reconstructed clothing. 3D Model: A. Moskvin

The hillshade model deriving from this 3D model was used to study the land usage in modern and past times (Draganits et al. 2018). In 2020, the dataset could also be used to plan a water beneficiation system for the village of Hamzelooh adjacent to the salt mine. Future planned steps include a combination of the UAV model with the close-up 3D models of the excavation areas, the core drillings and the geoelectrical data for further analysis (fig. 3).

3D documentation of the mummies and other finds also played an important part in the digital strategy of the project. The salt men displayed in the Zanjān Saltman and Archaeological Museum were documented with photogrammetry-based 3D documentation in 2016 while “Salt Man 1” was documented in the National Museum of Iran in Tehran in 2017. The 3D models allow studying the salt mummies without having to interfere with the conservation or otherwise endanger them through direct contact. Based on the 3D model of “Salt Man 4” and the thorough textile archaeological research, researchers at St. Petersburg State University for Industrial Technologies and Design recreated a digital avatar of “Salt Man 4” and his complete clothing and equipment (Moskvin, Moskvina, Kuzmichev 2020). Some finds like the equipment of “Salt Man 4” also were 3D documented during the excavation campaigns and during work in the Zanjān Saltman and Archaeological Museum. These models are not only used for the scientific study of the objects but are also part of the digital exhibition “Death by Salt. An Archaeological Investigation in Persia”[1] (fig. 4, A–C).



A B C

Fig. 4

Ceramic vessel found with Salt Man 4. Photo: German Mining Museum Bochum (A); Solid 3D model of the ceramic vessel found with Salt Man 4. 3D Model & screenshot: N. Schimerl, German Mining Museum Bochum (B); Textured 3D model of the ceramic vessel found with Salt Man 4. 3D Model & screenshot: N. Schimerl, German Mining Museum Bochum (B)

From Virtual Archaeology to a Digital Exhibition

Death by Salt. An Archaeological Investigation in Persia

Based on the excavations in Chehrābād, not only an international research project has developed over many years, but also the results of the research on the cultural heritage of the “Salt Men of Zanjān” were to be presented to the public. The exhibition “Death by Salt” has taken on this task. The exhibition’s narrative follows the archaeologists as they investigate the “Salt Men” as well as the salt mine and its surrounding area.

Different exhibition areas display the results, hypotheses and working methods of various disciplines such as archaeobotany or palaeomedicine. The connecting element of the individual exhibition areas are black and white drawings that visualise the results. In the end, all these illustrations are pieced together like a jigsaw puzzle, resulting in the hypothetical last day of “Salt Man 4” in a graphic novel. The visitors get to know the protagonist “Salt Man 4” as a young man, who is excited about his new work, and then follow him into the mine,

[1] The exhibition can be visited at www.death-by-salt.com; see also: Stöllner et al. 2020. At this point, we would like to thank the exhibition team. In particular: Sandra Badelt, Karina Schwunk, Manfred Linden, Katja Kosczinski, Fabian Schapals, Kristina Franke, Heinz Schaber and his team, as well as all the other people involved at the German Mining Museum and the other institutions involved.

A

B

Fig. 5
Excerpt from the Graphic Novel: Salt Man 4 tries to escape from the collapsing mine. Illustration: S. Saidi (A); Excerpt from the Graphic Novel: Salt Man 4 standing. He is the protagonist of the Graphic Novel. Illustration: S. Saidi (B)

Fig. 6
Mummy of Salt Man 4. Photo: K. Stange

where the tragic accident happens. Therefore, the illustrations not only show the research results but also appeal to the visitor emotionally. Furthermore, only what can be scientifically verified is shown in detail – the rest is left to the visitor's imagination (fig. 5, A, B, 6).

The aim of the exhibition is to make archaeological research accessible using the "Salt Men" as an example. For this purpose, the analogue exhibition was expanded by Augmented Reality (AR) and by the digital version further developed into a science-centre-like exhibition that is attractive to a wide range of visitors (Falk 2009). The digital dimension of the exhibition offers the possibility to expand the content for the respective target groups. Thus, academic literature is made available to the professional public. Interested visitors can discover models, interviews and animations in addition to the exhibition itself. Less interested visitors can get a stimulus from the graphic novel. The exhibition is optimised for different types of digital visitors (Gries 2016). It can be accessed from a wide range of devices such as PC, smartphone or tablet and offers further information on social media and a website.

Virtual Exhibition

The question arises as to what possibilities digital archaeology brought to the special exhibition "Death by Salt". The discussion about the term "virtual exhibition" – as a synonym for digital, virtual, electronic, online, hypermedia, web, or cyber – is neither new nor concluded (Schweibenz 2019; Samida 2002). After the digital turn, museums began to present their content on the internet. The variety ranges from the presentation of digital objects and collections to website-based exhibitions, to a 360° image of the exhibition sites, such as Google Arts&Culture. Virtual exhibitions are often seen as an "extension of the physical museum into the digital realm" (Schweibenz 2019) (fig. 7).

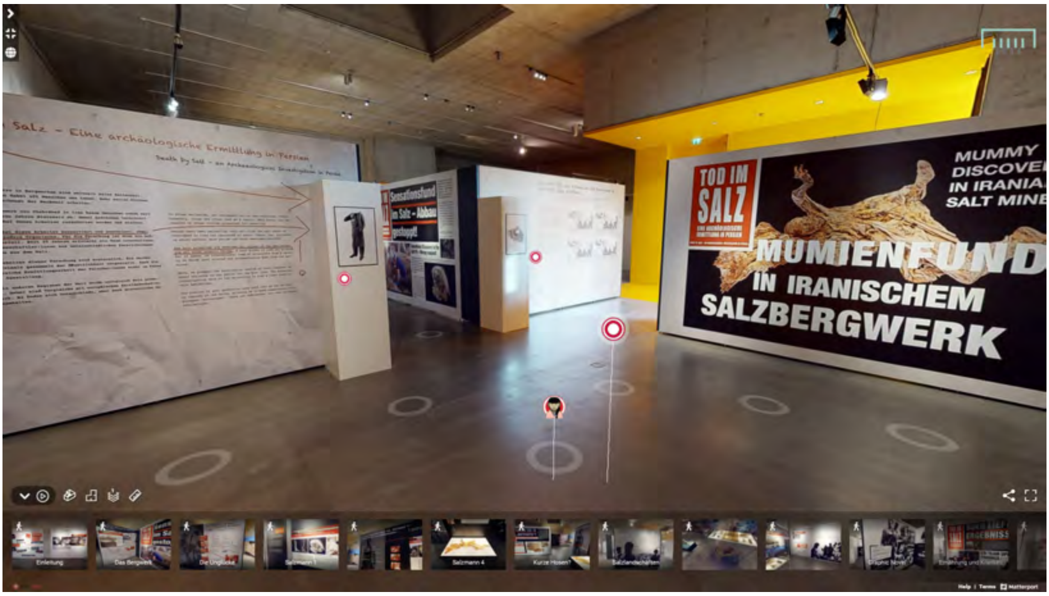


Fig. 7
Screen capture of the digital exhibition "Death by Salt".
Photo: N. Schimerl, German Mining Museum Bochum

The digital exhibition "Death by Salt" is a 1:1 scan of the exhibition spaces that has been expanded with a digital layer as well as digital objects. In this context, digital objects are understood as 3D models of the artefacts, interviews and illustrations that convey content (Döring 2016). For analogue exhibitions, it is not sufficient to simply put together objects in showcases. Visitors want to engage with the objects and the exhibited topic. For digital exhibitions, it is therefore even more important to enable the visitor to dive deeper into the different object layers. This means, it should be possible to examine objects more closely, supplement them with more information than can be seen with the blank eye and contextualise them not only historically but also with the scientific research methods, which were used in analysing the object (Fackler, Pellenghar 2019). In "Death by Salt", the digital layer offers visitors in-depth information and 3D models of the objects as well as information about the scientific research. 3D models generated by the researchers were made available to the public. The objects are contextualised and, in some cases, supplemented with further information. This matches the requirements for digital exhibitions as well as creates a synergy between digital archaeology and digital exhibition.

Unlike 360° panoramas with one predefined viewpoint in each room, visitors of "Death by Salt" can explore the exhibition area freely. Thus, they have the opportunity to accompany the researchers in their work, check their hypotheses and form their own picture of the results, just as they would during an on-site visit. It is possible for visitors to create their own narrative and not follow a predefined sequence. Visitors can visit the exhibition regardless of location and time. In addition, the digital exhibition has the advantage that it can be adapted to new research findings. In analogue exhibitions, this is either associated with high costs or is not done due to the short duration.

Digital Media in the Analogue Exhibition

The connection between virtual archaeology and digital exhibition is also pronounced in the analogue space. Thus, AR extends the exhibition. In this paper, augmented reality is understood as the extension of the real environment by a virtual level with the help of tablets and/or smartphones (Seitz, Kerber, Bernsen 2017; Grevtsova, Sibina 2018).

Objects such as the Salt Mountain and "Salt Man 4" are indispensable to the exhibition's narrative but cannot be physically exhibited in the museum. Based on the GIS and SfM datasets, a 3D print of the mine was integrated into the exhibition and enhanced with AR. Based on the highly detailed texture generated from the hundreds of photographs used for generating the 3D model, it was possible to colourise the 3D model accurately. Through AR, the 3D print of the excavation area visualises the finding places of the "Salt Men" and shows the stratigraphy as well as Sassanid and Achaemenid tool traces. An object that cannot be exhibited can now be shown in a museum through the means of digital archaeology while at the same time presenting some of the methods of digital archaeology themselves. "Salt Man 4" is a similar case. For conservation reasons, he is not transportable. Nevertheless, thanks to the digital data and the model calculated from it, he is now shown virtually in the exhibition. The annotations in the AR layer allow visitors to explore the research results at their own pace while simultaneously engaging with the 3D models of the mummy and his belongings. In this way, data and objects that are normally reserved for a small group of researchers are made accessible to a larger group.

The exhibition is therefore based on a trans-medial approach (Seitz, Kerber, Bernsen 2017), which, in addition to print and illustration, also includes the virtual extension of reality. This makes visible what would otherwise remain hidden to the visitor. Furthermore, the exhibition is based on the concept of the "blended museum", in which virtual and real forms of presentation are combined and mixed. So, the "Salt Men" can be visualised through AR, which also offers an interactive educational approach at the same time (Klinkhammer, Reiterer 2017).

Conclusion

Digital visitors have hardly been of interest to museums. Due to the pandemic in 2020, a change can be observed in this regard. Closed museums are increasingly relying on digital offers. "Death by Salt" is a prototype of an exhibition converting both analogue ways of presenting archaeological research results into the digital space as well as vice versa. Since the opening of the virtual exhibition in April 2021 more than 42.000 visitors from all over the world have viewed the virtual tour (as of July 2021). This particularly shows the importance of such formats for future museums and their digital offers.

Through the digital documentation created during the fieldwork and in the museums, an extensive library of virtual assets was accessible during the conception of both the analogue and digital exhibition. By using these datasets, the virtual exhibition could be realised relying on many more different layers of information than would otherwise have been possible. This shows how virtual archaeology has become a part of archaeological work and is now also making its way into the museums, opening the findings to a wider public. As a side effect, not only the data deriving from digital archaeology play an important part, but the discipline itself is provided a "stage" in the exhibition.

Finally, a prerequisite for an exhibition of this kind is not only having applied digital documentation methods during the research leading to the exhibition, but also the collaboration between archaeology and educational science. Without considering what visitors should take with them from the interaction with digital offers, the latter are threatened to become gimmicks without deeper pedagogical meaning. Therefore, virtual archaeology opens up new exhibition possibilities that are still largely unexploited.

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VIRTUAL REALITY VIDEO IN DIGITAL CULTURAL HERITAGE APPLICATIONS

Introduction

Cultural heritage now can be experienced. Digital technologies recreate original appearances of cultural monuments and life inside them. Interactive digital storytelling (Rizvić et al. 2017a) introduces the viewers to historical information through short interconnected stories resolving the problem of short attention span of the audience and their reluctance to read. Virtual, Augmented and Mixed Reality technologies transfer the users in the past. An important part of digital cultural heritage applications is VR video.

As rightly stated in (Wohl 2019), VR video "has been one of mankind's oldest and most persistent dreams." The idea of creating an alternative constructed reality to share one person's unique experience was invented in the first rock art drawings. Nowadays, 360° cameras are recording their whole surroundings. The viewer is no longer in front of the screen, but "inside it". VR video is not only a 360° camera recording, but any other content recorded, computer-generated or composited, saved in a format supporting Head Mounted Display. Having the audience inside the shot or computer-generated environment, the classical film language grammar and production rules are not applicable. There is no composition of the shot using camera positioning, no close-ups or other means film and theatre directors have been using to attract the attention and stage the story.

In this paper we present our experience in 360° filming and VR video production in order to assist the future VR producers and directors. Our work was focused on cultural heritage topics. In the Related Work section we will discuss other pioneering VR video projects, with their advantages and drawbacks in comparison with ours. In the VR Video Cinematography section 360° cameras, shot composition, lighting and sound recording challenges will be considered. In the Experiences section we will present our solutions to the above-mentioned problems within several VR production projects. In the User Feedback, selected comments from user experience evaluation studies will show how the users react to VR video. In the last section, we will present our conclusions and future work.

Related Work

Many film and video researchers or avant-garde filmmakers are exploring the possibilities of 360-degree video recording. We can even say that popularity of 360° video recording has started to rise with Virtual Reality headsets (VR Headset) falling in price and becoming more available for home usage (Baobab Studios 2018). However, 360° video recording is a completely new approach to how we can record video and many rules are still not set. Yet many of the existing rules cannot be completely applied to 360° video shooting. These differences become even more distinct if we view 360° videos using Virtual Reality headsets. Austin Baur describes the work on the set of a VR film and talking to the film writer/director about the challenges faced while preparing the film (Baur 2016). Guiding the viewer's interest in 360° video and blocking for actors were the biggest encountered problems, which falls in line with things we were spending most of the time solving.

However, a completely new area of interest has opened up with the rise of the VR headset market (Mateer 2017). Digital content for preserving and presenting cultural heritage has risen to a new level. 360° video has allowed us to film natural locations and put the user in the middle of different cultural heritage sites. Combining these videos with artificially recreated environments, users can feel as if they are travelling through time while watching the content everywhere around them. To enhance the feeling of immersion, placing actors inside the video allowed us to emphasize the importance of storytelling (Elmezeny et al. 2018). This is confirmed in the Livia's Villa project, where actors were 3D modeled in the first version, and then changed with the real actors in the second version of the application. It gave users a greater feel of belonging to the environment and more interest in the story the actors told (Pietroni, Forlani, Rufa 2015).

We first tried this approach in an interactive digital story about a ship that sunk near Kyrenia around 288 BC (Rizvić et al. 2017b). Actors in 360° videos about cultural heritage can greatly increase user immersion. They significantly contribute to storytelling and are adding another emotional level to the experience. Actors' contribution to VR videos is described in (Rizvić et al. 2019). The story is about Baiae, an ancient Roman town on the northwest shore of the Gulf of Naples. Following the experience of these works, and doing different field tests, we proceeded with our own projects. The primary task was to find equipment that would suit our video and audio needs and come up with solutions on how to record both video and sound on the set.

VR Video Cinematography

The 360° camera market is rapidly growing. We could actually say the same for the camera and technology market in general, but the changes in 360° cameras are much more significant from generation to generation. The camera of choice for our projects was Garmin's VIRB 360. It is a consumer-level camera, but with a higher resolution than most of the cameras of that level. Also, it is very fast to work with, since it can show 4K resolution in real-time. For filming in 5.7K, it has dedicated software which stitches the video quickly afterwards. When choosing a camera to work with, one has to pick two traits out of three: Fast, cheap, good (Wohl 2019) and this was just what we needed for our projects.

But we faced another challenge. In conventional video, framing is the main tool for telling a story. However, in 360° video, everything is inside the frame. We had to decide whether we wanted the action to happen everywhere around 360 degrees or narrow it down to 120–150 degrees in front of the user. This is still debated by many authors. Some of them believe in the former and others in the latter (Passmore et al. 2017). We decided to go for full 360-degrees but slower-paced storytelling. We kept a similar approach throughout our projects. This decision, however, made lighting and sound equipment placement even harder than it already is in 360° video. The all-seeing eye of the camera pushed us in two directions for the lighting setup. Either use a lot of natural light, or place the light inside the frame and make it a part of the shoot. Many 360° video creators are choosing similar solutions (Wohl 2019).

Similar difficulties are encountered with sound equipment placement. On usual sets, a hypercardioid microphone (or more commonly known as a shotgun microphone) is used to record dialogue. However, they are very inconvenient for using in 360° video. We decided to rely on lavalier microphones placed on actors and around the set. This decision made sound post-production more demanding, but solved the problems of microphone placement in shootings on the sets. We still used shotgun microphones for recording actors on green screen when we did not need the actor to actually be on the location. After making these decisions and structuring our ideas around them we were ready for the upcoming filming.

Experiences

iMARECULTURE was our first project with newly acquired equipment. At the start of the project, we still did not use a 360° camera for filming. All of the filming was done with Sony A7s II camera with actors in real locations or in the studio with green screen. The VR environment was programmed as actors were added to virtual space. We also added screens inside the VR where videos we filmed on the locations were played. It was our starting point for analyzing users' behavior in VR, and how actors can be used inside the space.

VR Simulation of Mostar cliff diving & Sarajevo War Tunnel VR

Two smaller projects, perfect for our first tests with 360 VIRB Camera, consisted of two parts. One where we model the VR environment and the other with the 360° video. The first was the VR Simulation of Mostar cliff diving project where we filmed the location of a bridge in Mostar, Bosnia and Herzegovina, using the 360° camera, as well as an interview with a famous cliff diver. Users can listen to the interview while virtually standing in the middle of the crowd below the bridge, and after passing the quiz proceed to jump off the bridge. The latter part is done in Unity 3D. We took the same approach in the Sarajevo War Tunnel VR project. We filmed real locations with the narrator walking around the scene of a 360° camera talking about his experiences from those locations in wartime. After listening to all of his stories, the user moves to the museum, which was also filmed with the 360° camera. While standing in the middle of the museum he/she answers questions from the stories and gets the chance to virtually walk through the tunnel that saved Sarajevo during the siege in the 1990s.

Roman Heritage in Balkans & Old Crafts Virtual Museum

Combining the techniques we used in the iMARECULTURE project with the Mostar cliff diving and Sarajevo War Tunnel experiences brought us a new way to tell a story in virtual reality domains. In the Roman Heritage in Balkans project, we visited eight Roman sites around the Balkans and filmed them with a 360° camera (fig. 1). With the help of historians and archeologists we collected information about those sites and how exactly they looked in Roman times so we could model them and recreate them inside our virtual space. The third step was filming actors on a green screen. An actress played several characters from the Roman period. Combining all these parts we created a VR application where the user would be first taken to the real location. The actress would meet him/her there and, while telling the story, the environment would change to the reconstruction.

We applied a similar approach while developing the Old Crafts Virtual Museum project. This time the actor played different craftsmen, on green screen, explaining to the user what their craft was and where they are today. We again used 360° videos from real locations, as well as a 360-degree illustration.

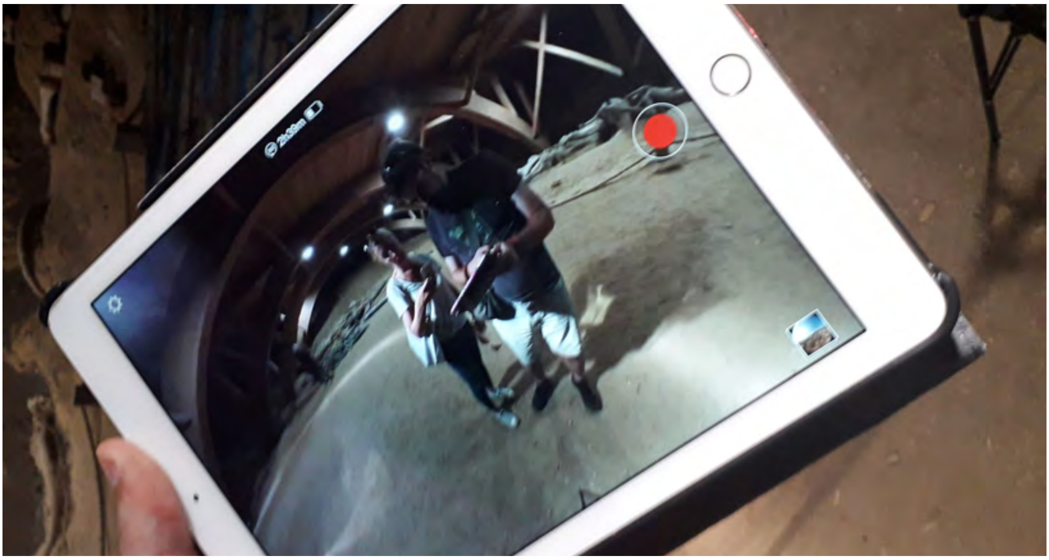

Fig. 1
Controlling 360 camera through iPad. Photo: S. Rizvić

Nine dissidents – VR experimental film

The next challenge was the first Bosnian VR film. The film tells, in a satirical way, a story of Bosniak writers who were prosecuted during the socialist regime in Yugoslavia for their dissent with the Communist party. The action takes place in an improvised courtroom, where the solicitor of revision is trying to convince the judge and jury to rehabilitate these writers, while the solicitor of history, together with the jury, is trying to prevent him.

Careful planning was needed in order to execute this project. Whole filming is happening in one location – an improvised courtroom. That gave us flexibility in choosing the location since we didn't need a real courtroom. We selected a room with a huge window on one side and placed a huge diffusion filter outside. This now became our primary source of light which was also very soft and evenly distributed around the room. The camera was placed in the front part of the room between the solicitor of revision and the judge (fig. 2). Behind the solicitor are the people sitting in the courtroom, and the solicitor of history is walking around the room. Since there was no room for shotgun microphones, we placed lavalier microphones on each of three actors, plus a fourth one between the people in the back, to have it both as an ambient microphone and chaffer from the audience. The whole film crew was located in a hallway in front of the room. We used the VIRB app on the iPad to have a live view for the cameraman and the director. Filming was done in several parts to make it easier for the actors to learn the lines, and also to denote passage of time in the courtroom. We tried to make the cuts as easy as possible in the editing to avoid disorienting the users (fig. 2).

Battle of Neretva VR

Combination of VR Gameplay and VR Video was the goal of the application we made for a museum dedicated to the Battle on Neretva (a famous WWII battle that took place around the town of Jablanica in the former Yugoslavia). Parts with video were devised to tell the users about the Battle, as well as instruct them on what they should do in the gameplay part, experiencing the Battle as partisans. While in the "Nine Dissidents" the user was an unseen observer, here he/she is now actively participating in the video. The actors are playing the partisan commander guiding the player through the VR application.

Fig. 2
Nine dissidents filming in 360. Photo: S. Rizvić

Filming the scenes was also more difficult now, since we had to create improvised partisan headquarters. Our set designers' team did a wonderful job in a small hallway with two small windows (fig. 3).

We set a couple of light bulbs around the set which played in the scene as well as helped to light it. The camera was placed in close proximity to the commander, and several other actors were dressed as soldiers standing around the user amplifying the feeling of being one of the soldiers. Lavalier microphones were placed on both the commander and the soldiers around, and additional ambience sound was recorded using a shotgun microphone. This setup allowed us to have a darker themed atmosphere but still provided enough lighting for the actors from the light bulbs placed around. Everything was edited again using Adobe Premiere and After Effects and exported in h.264 VR codec.

User Feedback

In order to understand how successful these pioneering endeavours were, we conducted user experience evaluation studies for each of the projects mentioned. The selected users watched the videos and applications and conveyed their impressions using a qualitative and quantitative user evaluation methodology. The common general impression of the majority of users was that VR video is very immersive and presents a completely new experience in comparison with classic video. The particular impressions and comments depended on the familiarity with the use of VR headsets. Younger audiences and gamers had stricter criteria as they compared our projects with big-budget computer games. The users less familiar with gaming needed time to understand how they should interact with VR applications.

Nine dissidents VR movie was very much appreciated. Some users who watched it on YouTube at the beginning did not know that they needed to interact and move the view around. All the viewers interviewed stated that they felt as if they were in the scene. They appreciated the length of the movie, the storytelling and production.

The Mostar Bridge Diving VR project was one of our most loved ones. The viewers who have not been in Mostar before felt as if they were there. The 360° videos transferred them to the location and made them fully immersed (Selmanović et al. 2020). The real bridge divers, after the virtual jump, said: "the feeling is the same, only it does not hurt!"

Fig. 3
Partisans' headquarters 360 filming. Photo: A. Hodzic

VR videos created for the iMARECULTURE project were highlighted as the best part of the Dry visits application. Viewers appreciated the use of actors (Rizvić et al. 2019; Škola et al. 2020) and felt as if they were present in the life of the Roman Empire.

In Sarajevo War Tunnel VR the 360° videos prepared the users for a virtual visit to the tunnel and familiarized them with the location. The audience of the Roman Heritage in the Balkans project stated that the VR videos made their perception of archaeological locations more complete and understandable.

The Old crafts Virtual Museum was perceived as an opportunity to learn about crafts and craftsmen before visiting their workshops. The illustrator who created the background for the virtual environment said that this was the first time he was able to "enter his own drawing". The users appreciated the opportunity to learn the meanings of a large number of crafts names, today mostly forgotten.

In the Battle on Neretva VR project the users enjoyed the experience of the battle participant. They stated that their favourite moment was meeting comrade Tito after the successfully completed mission.

Some users reported motion sickness and discomfort, particularly in applications containing movement through the virtual environments. The VR video itself was not reported as uncomfortable or disturbing. They stated that they did not miss a single part of the story due to the 360° field of view. On the contrary, they felt as if they were participants of the story (Rizvić et al. 2021).

Conclusions and future work

VR video is still a new area, and although some rules have already been established by Jaunt, Google and Vimeo, not many empirical studies have been conducted to ratify or challenge these guidelines (Passmore et al. 2017), and also many other rules are still not defined at all. Both directors that worked with us had problems with directing the scene in a classical way. They both agreed that directing in 360° video was more like directing in theater than in film.

Comparing these with filming Baur was part of (Baur 2016) as well as Pope (Pope et al. 2017) noting that theatre directors use space in complex ways for narrative purposes, and that these basics can also be used for VR, we can conclude that VR directing needs its own set of rules.

A very important aspect of preparation for 360° filming is camera placement and blocking. Both director and cinematographer must have in mind that the whole set is in the frame, and no additional framing can be made. The action should be appropriately distributed around the scene, but with special care so as not to overwhelm users and cause motion sickness.

The cinematographer, sound engineer and set designer should plan the set design together so that they could decide where to hide microphones and lights inside the scene. If the planning is executed well, the placement of lights and microphones can enhance the quality of the video. Adding the lights outside the scene to serve as indirect light sources can help a lot. The scene we filmed for Battle of Neretva VR had a long hallway leading away from our set, so it was not in our camera frame. Setting the light source from the hallway contributed to our scene without the need for justification.

An important aspect of sound is also post production. Ambisonics is a format needed for VR film to function properly. Sound sources must be mapped to the position in post production allowing the user to hear the sound differently as he/she is turning his/her head around the room. This contributes to a higher immersion of the user and the feeling he is really a part of the video.

We plan to further explore the possibilities of 360° filming and creating VR videos and applications. Camera tilting and panning is impossible in 360° video, but moving the camera itself is not, and that will be one of our next steps. We are fully aware that any movement in a 360° video can contribute to motion sickness, but we believe that well planned moves will minimize the unwanted effect.

Another interesting area for exploring is adding more separate actions and stories into the same frame. It would increase the replayability of the VR film and add another layer for analyzing content between users showing different areas of interest and ways to watch the film. Lastly, better quality cameras with larger sensors and higher dynamic range would increase the possibilities of filming in different conditions.

Whether one is an early adopter of VR or still skeptical about its abilities or everyday usage, one thing is certain: the virtual reality market is increasing and VR is taking its place as a media format. In the near future we can expect much more VR content and technology available to the ever-growing audience.

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PHOTOGRAMMETRY CASE STUDIES

Conservation of cultural heritage requires a critical understanding of the significance, condition, and complexity of a place. Documentation is an essential element in building this understanding. It is a critical component of the conservation planning process and provides a long-term foundation for the monitoring, maintenance, and management of a site. Equally important, good documentation ensures that knowledge of heritage places will be passed onto future generations. Good conservation of our cultural heritage is based on informed decisions. The information needed to make these decisions is, in part, obtained through the use of documentation and recording tools. Knowledge of these tools and their use is readily available; however, many of the decision makers are unaware, uninformed, or unconvinced of their benefits. Several reasons for this include a misunderstanding of the tools and techniques or intimidation by technology or language. There is no universally accepted definition of photogrammetry. The definition given here captures the most important notion of photogrammetry:

Photogrammetry is the science of obtaining reliable information about the properties of surfaces and objects without physical contact with the objects, and of measuring and interpreting this information. The input is characterized by obtaining reliable information through processes of recording patterns of electromagnetic radiant energy, predominantly in the form of photographic images. The remotely received information can be grouped into four categories:

1) geometric information involves the spatial position and the shape of objects. It is the most important information source in photogrammetry.

2) physical information refers to properties of electromagnetic radiation, e.g., radiant energy, wavelength, and polarization.

3) semantic information is related to the meaning of an image. It is usually obtained by interpreting the recorded data.

4) temporal information is related to the change of an object in time, usually obtained by comparing several images which were recorded at different times.

Working as a documentarist in the archaeology department gave me a rare insight into the benefits of new technologies as I progressed in adopting faster and more reliable techniques in documenting a large variety of sites and objects. My experience starts with methodology and equipment unchanged since the 1960's: drawing on graph paper, measuring with a measurement tape and heights measured with a theodolite. Photographing is done as an addition to drawn documentation or as documentary photos of objects with a measurement scale beside the object. Very soon I took part in international[1] archaeological excavations where the new equipment and software was presented to me. It was much more complex and detailed documentation, but collecting of information was much faster. Software was

[1] Roman-Germanic Commission (RGK) and University of Kiel.

AutoCAD-based Kubit PhoToPlan and TachyCAD – my first work in photogrammetry. It was still 2D output with the possibility to make a 3D object by rotating different 2D planes and connecting them together. The process was relatively simple. You would start with placing the control points on the ground, measure their x, y and z coordinates and then take photographs that capture a minimum 4 of those points. The software would do rectification of photos (projective transformations) also removing lens distortions. The result was scale 1:1 2D photo that can be further processed in AutoCAD (fig. 1).

Fig. 1
Photogrammetry of one archaeological layer, Neolithic settlement, Okoliste, Bosnia and Herzegovina. Here we can see blending of one layer (same height) even though it was documented as excavated, in different times (Hofmann 2006)

This method was much more important as it is no longer documenting interpretation. It is raw documentation, with possibility to be reinterpreted many times as we gather more and more new information throughout years of excavations and research. It was a key reason why my choice would always be photogrammetry. After this, it is possible to design presentation methods of different features as it is necessary for a wider audience to understand easily what was done and why (fig. 2, 3).

At that time, Kubit offered 2 types of photogrammetry:

1. Photo rectification according to control points – where you place min. 4 control points on the object to be photographed and measured, take a photo of the object, measure control points with a total station, assign the measured control points to the ones in the photograph and adjust the desired setting (fig. 4–6).

2. Photo rectification according to geometry – In the original photograph, the shown objects normally appear distorted because of the position and orientation of the camera. First we need to set up a grid. For each rectification three control distances have to be taken from the object. They must be well distinguishable in the photograph (fig. 7–9).

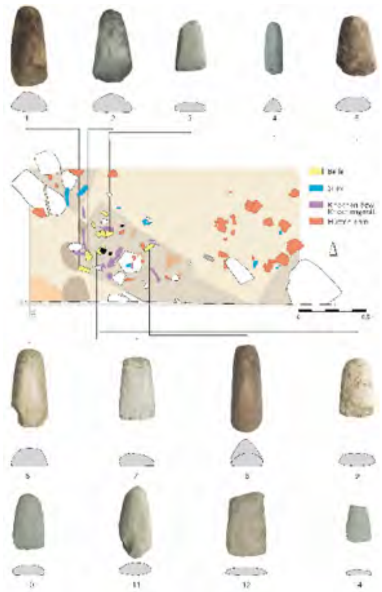

Fig. 2
Distribution of axes on the site (Hofmann 2006)

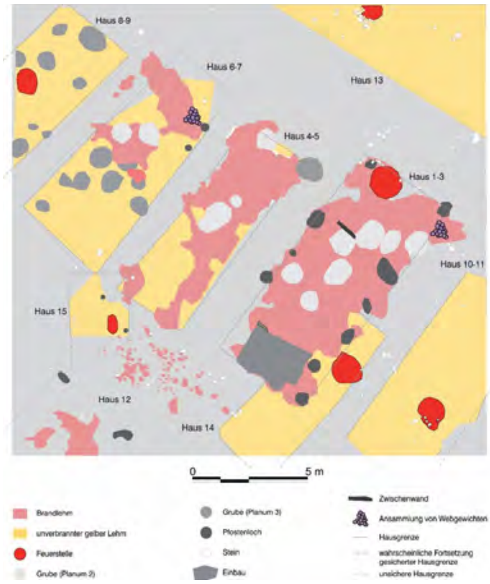

Fig. 3
Distribution of different types of soil (Hofmann 2006)

Fig. 4
Rectified photos according to placed and measured control points[2]

Fig. 5
Removing what doesn't belong to the rectification plane

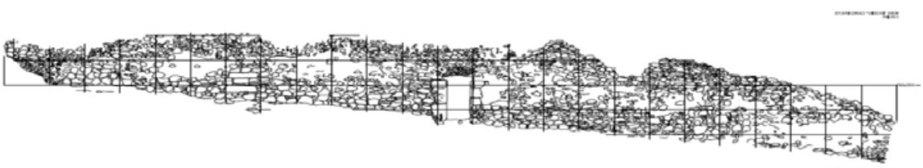

Fig. 6
Resulting AutoCAD drawing

[2] This is part of the documentation of an archaeological excavation of the medieval Old Town Visoki, Visoko, BH, done by Tatjana Mijatovic.

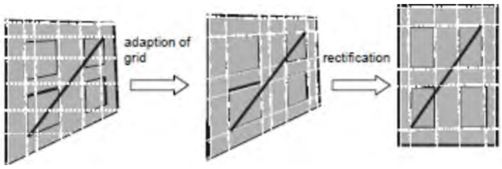

Fig. 7
Schematic illustration of working process

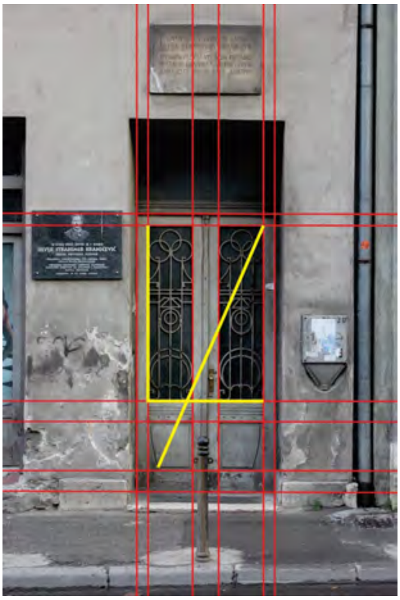

Fig. 8
Setting up a grid of a parallel lines and marking 3 measured distances on actual doors

Fig. 9
Result, measurable rectified photo of the doors, scale 1:1[3]

What propelled the use of photogrammetry is freemium Autodesk 123D Catch. It was the first possibility to generate a 3D model without a 3D scanner and to learn about the process without having to worry about the cost. It was also an announcement for all other professional software that came after with even more possibilities and precision. The costs of purchasing a 3D scanner and software for it was sky-high compared to the costs of buying a solid digital camera. Today, the relatively expensive software gives us the opportunity for a Pay-Per-Input license while the complete software remains free to work on the model.

Example of an Austro-Hungarian Villa, corner of the Ljubljanska and Trnovska street, Sarajevo BH

A building of high architectural and ambient value. Heavily damaged during the war and left as ruin with a single family living in one of the apartments. It was marked as dangerous, prone to collapsing, fast documentation needed. There was previous documentation except the document of the current state. It was possible to do in one day as terrestrial photogrammetry using an EOS Canon 550d and processing in Autodesk 123D Catch (fig. 10, 11).

[3] Documentation done for purpose of cataloguing all art nouveau doors in the city of Sarajevo, done by Tatjana Mijatovic.

Fig. 10
Photogrammetric model and photographs used for it

Fig. 11
Level of precision of marked area

Example of documenting Old fortress in Blagaj near Mostar, BH

The old medieval fortress of Blagaj was made using drone aerial photogrammetry. Beside good quality and reliable photographs, the drone captures coordinates of the place where photos are taken, so the generated model is completely georeferenced, in real size, scale 1:1. There was little contrast between shaded and sunny parts of the fortress, so it was decided that everything will be done from one attempt. The geometry is fairly simple, so there was no need to combine terrestrial and aerial photogrammetry. Everything could be captured by drone. Location is not reachable by car, so there was no source of electrical power to recharge batteries for the drone. This affected decisions about how many photographs should be taken to avoid getting the low-detailed model (fig. 12, 13).

Fig. 12
Position of the drone while taking photographs. Drone circled on 3 different heights around same centre point in fortress

Fig. 13
Final outcome, photogrammetric model scale 1:1

Example of St. Mary Church with St. Luke Tower, Jajce, BH

Photogrammetry was used as a documentation for my master's thesis at the Department of Theory and History of Architecture and Preservation of Cultural Heritage, The Faculty of Architecture in Sarajevo. This type of documentation finally enabled me to capture the complex geometry of what seems to be flat walls, but is far from being flat. The importance of such documentation is enhanced by the fact that the newly designed object needs to be precisely placed inside the existing one, which is a national monument of BH. The photogrammetry was done completely by drone because this building has no roof and flight was possible inside the "interior" as well. No method could be applied in the interior of the bell tower because it is filled with a steel structure supporting the bell tower itself to prevent it from collapsing (fig. 14, 15).

Example of a stone fragment from the Handanija Mosque

The Handanija Mosque in Prusac (1617), built in the classical style of Ottoman architecture, represents an important example of Bosnian-Herzegovinian religious heritage due to the numerous original parts from the 17th century that were found in its interior and due to its long cultural and religious history.

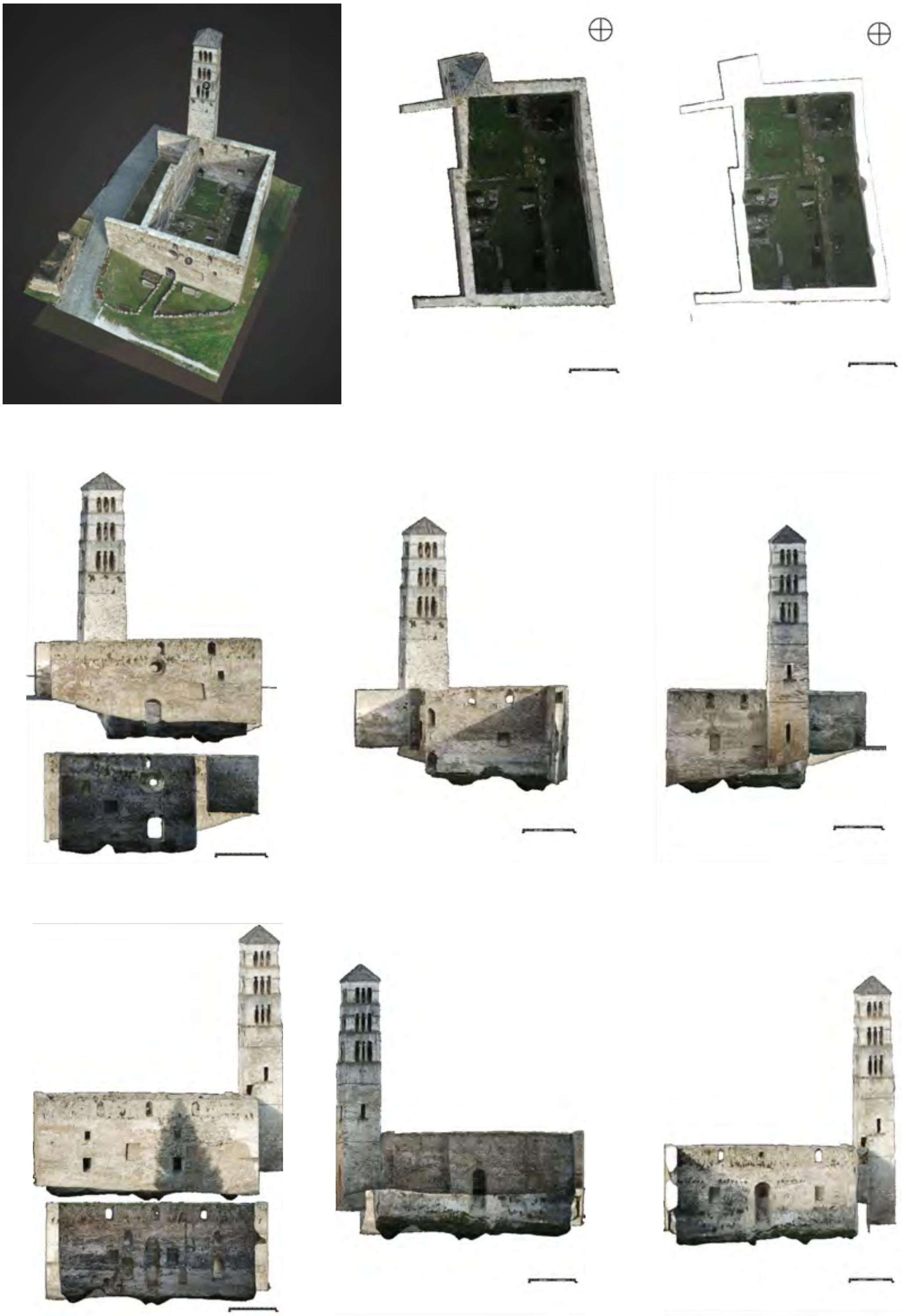

Fig. 14
3D model and all architectural drawings
(top view, ground view, facades and cross sections)

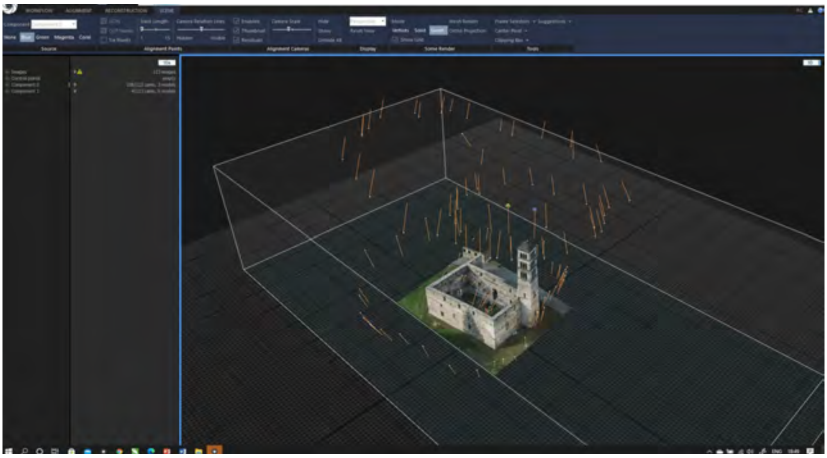

Fig. 15
Positions of the drone

This is one of the remaining original stone fragments found during in situ documentation after the mosque destruction. The mosque was heavily damaged by shelling during the war (1992–1995). The restoration started in the summer of 2003 and all works were completed in the autumn of 2005. Majority of the fragments were reused and built in their original position. Photogrammetry used in this case is a good example of newer possibilities photogrammetry software is offering: having a detailed 3D model of all sides of the actual object. This was done by the help of a Foldio360, mini studio with a turntable, though it is not necessary for getting the same result (fig. 16, 17).

Fig. 16
Photogrammetric model
of the stone ornament

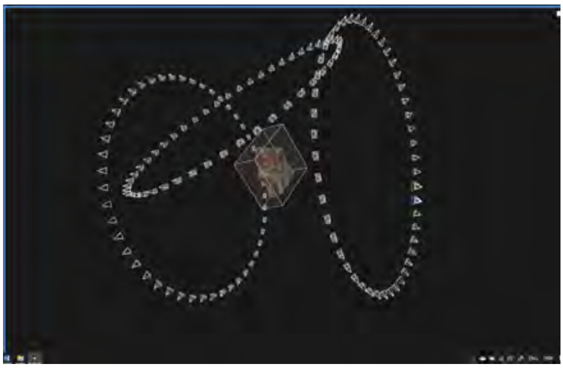

Fig. 17
Position of the camera needed
for generating total model

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[4] All models can be seen on SketchFab, https://sketchfab.com/tatjana_mijatovic.

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ВОЗМОЖНОСТИ КОМПЬЮТЕРНОЙ РЕКОНСТРУКЦИИ РАЗБИТОГО КЕРАМИЧЕСКОГО СОСУДА

Введение

В ходе археологических раскопок предметы материальной культуры очень часто обнаруживаются разрушенными или в виде отдельных фрагментов. Многие изделия попадают в культурный слой уже в сломанном и деформированном состоянии. Изменения их формы происходят и во время длительного пребывания в грунте, а также под воздействием разных природных и антропогенных факторов. Чтобы восстановить первоначальный облик находок требуется значительное количество времени даже квалифицированным специалистам, а для реставрации еще необходимо соответствующее финансирование.

Такой массовый и разрозненный поселенческий материал, как фрагменты от разбитой керамической посуды, может вообще не использоваться для полной реконструкции ёмкостей в силу недостаточного количества имеющихся частей. Компьютерные технологии в данном случае пока не являются эффективными помощниками, хотя при создании мощной базы данных с хорошо документированной керамикой и с развитием эффективного программного обеспечения вероятность реализации подобной деятельности вполне реальна. Работа в этом направлении набирает обороты не только за рубежом, но и в России (см., например: Зайцев и др. 2021). Более благоприятной является ситуация, когда разрушенный глиняный сосуд находят в жилище, хозяйственной яме, ритуальном объекте или в могиле. Тогда есть возможность его собрать и склеить. Но часто такую работу не получается полностью выполнить из-за того, что каких-то кусков просто не хватает или они повреждены до неузнаваемости. Реставраторы обычно решают эту проблему простым способом: заделывают отсутствующие места мастикой или гипсом (Кирьянов 1950). Археологи традиционно осуществляют графическую реконструкцию, руководствуясь ранее сложившими представлениями (Грязнов 1946). Имеются попытки применения компьютерных технологий для моделирования керамических сосудов на основе обнаруженных фрагментов или для формирования недостающих частей (Беговатов, Кочкина 1993; Сингатулин 2010; Малков, Харинский 2018; и др.). В настоящее время вопросы восстановления внешнего вида археологических находок и успешной автоматизации работы с массовыми материалами раскопок остаются актуальными.

При разработке методики реконструкции формы предметов конечной целью является построение математических моделей геометрии этих объектов. Полученные результаты должны помочь при проведении исследований и дальнейшей реставрации. Уже на основе предварительной компьютерной визуализации для этого могут быть выработаны необходимые решения, а также получены сведения о многих физических свойствах изделия. Модель с полностью восстановленной геометрией позволит определить массово-центровочные и инерционные характеристики конкретного объекта, выполнить его измерения, поставить численный эксперимент по определению напряжённо-деформированного состояния, устойчивости, тепловых, оптических и других свойств. Для этого ещё нужно дополнить геометрическую модель физическими свойствами, смоделировать внешние условия её использования и выполнить соответствующие расчёты. По геометрической модели можно реконструировать технологию производства и способы механической обработки изделия, проверить саму возможность и качество его изготовления выявленным способом. Кроме того, возможна графическая имитация процесса создания предмета материальной культуры. Для этого нужна информация о предполагаемом технологическом процессе, оборудовании и другие сведения, связанные с конкретным производством.

Проблема решения перечисленных и других задач, тем более в которых учитываются физические законы, предполагает применение дифференциальных и интегральных уравнений. Нахождение их решений является крайне сложной задачей. В данной статье не станут затрагиваться расчёты, связанные с физическими процессами. Будет только рассмотрена возможность восстановления чисто геометрических характеристик объекта, не требующих привлечения дополнительной информации. Данный подход обеспечивает своего рода компьютерную «реставрацию» древнего изделия, а также создает условия для реализации современных возможностей его всесторонней презентации и дальнейшего комплексного изучения.

Материалы и методы

Для решения обозначенной задачи в качестве образца привлекался керамический сосуд с утраченными частями, которые составляли 23 % поверхности ёмкости (рис. 1). Он был обнаружен в виде отдельных фрагментов при раскопках кургана № 89 на памятнике Тыткескень-VI в Чемальском районе Республики Алтай (Россия) и относится к характерным изделиям пазырыкской культуры скифо-сакского времени (Кирюшин и др. 2020, с. 51; рис. 55; 56, 1; 58, 9; 59, 1). Была предпринята попытка физически и графически восстановить разбитую ёмкость. Однако при склеивании оказалось, что часть фрагментов по разным причинам утрачена. Кроме этого, не везде обломки хорошо состыковались друг с другом из-за разрушения краёв, что отразилось на внешнем виде восстановленного древнего изделия (рис. 1). Эти и другие изъяны не способствуют адекватному восприятию и презентации сосуда, а также усложняют получение объективной информации о нём и о технологии его изготовления.

Графическая реконструкция (Кирюшин и др. 2020, рис. 59, 1) представлена в одностороннем и схематическом порядке и носит больше условно демонстрационный характер. Для частичного преодоления выше обозначенной ситуации была предпринята компьютерная «реставрация» утраченных мест. Сложность такого процесса заключается в том, что основные пробелы приходятся на довольно крупную область тулова. Заполнение отсутствующих мелких фрагментов решается значительно проще и не вызывает больших погрешностей. Поэтому стоит сосредоточиться на представлении процесса компьютерного «реставрирования» самого большого отсутствующего участка.

Рис. 1
Склеенный керамический сосуд пазырыкской культуры

Для выработки адекватного алгоритма необходимо придерживаться определенной логики, согласно которой будет осуществляться намеченный процесс. Учитывая то, что представленный керамический сосуд является ручной работой, а его геометрия слабо ограничена какой-нибудь механической технологией, кажется, что точно восстановить такую большую область утраты почти невозможно. Основная проблема заключается во множественных вариациях восстановления отсутствующей стенки тулова сосуда, и важно доказать, что процесс компьютерной «реставрации» отражает действительно исходную форму изделия.

Специалист-реставратор, осуществляя подобную работу на реальном горшке, исходит из своего опыта, который базируется не только на большом количестве виденного им материала и на понимании самого процесса изготовления, а зачастую и на представлении, каким должно было быть изделие в гипотетически идеальном случае с учётом качества работы мастера. То есть важно понимать задумку автора-изготовителя и его реальные возможности. Именно последнее утверждение стоит использовать для компьютерного способа «реставрации», который нуждается в чётко поставленной задаче и обоснованной логике исполнения.

Задача восстановления утраченных фрагментов керамического сосуда направлена на построение поверхности, имеющей определённые радиусы кривизны в каждой её точке или ограниченном сегменте. Поэтому сначала надо проанализировать форму сосуда для определения максимальных допусков, уже существующих в его геометрии. Анализ можно проводить с помощью продольных и поперечных сечений, проходящих в заданных местах таким образом, чтобы эти сечения, соединяясь кривыми, наиболее полно повторяли форму сосуда, в результате получая единую трёхмерную форму. Данный процесс построения поверхности по её сечениям, по сути, является плазированием, применяемым для построения сложных математически не описываемых сплайновых поверхностей (рис. 2). В заданном формате можно построить бесчисленное множество нормальных сечений, которые отличаются направлением и их количеством, а следовательно, и точность расчёта ограничивается лишь временем и вычислительными мощностями.

Анализ полученных сечений хорошо показывает, что рассматриваемый керамический сосуд не являлся телом системного механического вращения, т. е. он не был изготовлен на гончарном круге. Но автор-изготовитель явно стремился к тому, чтобы сделать его «ровным», т. е. достичь определённой геометрии тела вращения. Будем считать это пределом расчётов с учётом погрешностей мастерства и технологии, заложённых в геометрии данной ёмкости (кринки).

Определение того самого «мастерства» изготовителя и возможностей его технологии с точки зрения геометрических выкладок сводится к определению погрешности от той геометрии, которую хотел достичь гончар. Среднеквадратичное отклонение по сечениям варьируется в пределах 5,4 % от округлости по всем сечениям (так же, как и условные центры вращения для каждого из сечений). Учитывая данную информацию и предполагая, что в потерянной геометрии сосуда эта закономерность явно сохранится, можно построить некий коридор максимумов и минимумов координат для каждой точки сосуда, а после определить главные кривизны поверхности, которые являются максимальной и минимальной кривизнами соответственно.

Для того чтобы реализовать намеченную программу, необходимо сначала получить некое облако точек, на основании которого можно построить поверхность. Для построения каждой точки достаточно определить три координаты и иметь функции выполнения операций над её радиус-вектором.

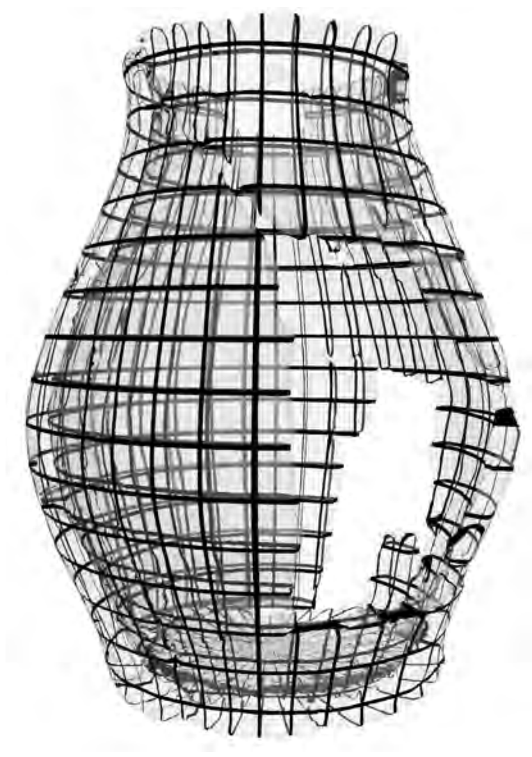

Рис. 2
Построение горизонтальных и вертикальных сечений сосуда

Это потребуется для ответа на вопрос о том, принадлежит ли точка области условной поверхности сосуда с учётом определённых погрешностей (т. е. надо классифицировать точку). Чтобы установить принадлежность точки некой двухмерной поверхности, необходимо найти все точки, принадлежащие всем сечениям с условием их пересечения с границами области. Это довольно ресурсоёмкое занятие для обычного компьютера, поэтому был определён шаг сечений в 1 мм, что позволило сократить количество анализируемых сечений до относительно небольшого числа. Далее легко определить принадлежность рассматриваемой точки заданной области. Результатом явилось облако точек, в пределах которого теоретически может находиться геометрия сосуда (рис. 3).

Обозначенное облако точек весьма неоднозначно определяет поверхность. Такую область изменения параметров могут иметь очень многие поверхности. Для построения недостающей части сложной формы необходимы предварительные построения, упрощающие дальнейший процесс. Для нас практическое значение будут иметь пространственные линии и точки, которые находятся в области заданных параметров. Для последующей реконструкции поверхности можно построить два семейства ортогональных, в точке их пересечения, кривых при различных значениях критериев – максимума и минимума. Два таких семейства кривых образуют сетку. Через каждую точку можно провести множество различных кривых, и величина их достоверности будет иметь одно и то же значение, несмотря на то, что у них разная кривизна. Единственным критерием отбора здесь может являться лишь то, что кривизна такой кривой должна быть в интервале кривизны, определяемом максимумом и минимумом нормального сечения в данной точке.

Рис. 3
Сформированное облако точек
(масштаб размеров точек 10:1)

Для реализации такой работы использовались NURBS-кривые (неоднородный рациональный фундаментальный сплайн), построенные на множестве неравноотстоящих узлов. NURBS-кривая представляет собой линейную комбинацию кусочно-полиномиальных функций заданной степени и позволяет строить кривые заданного порядка гладкости.

Допустим, что берётся некая кривая линия в виде соединённого ряда точек. Кривизна такой линии будет меняться в зависимости от того, какие именно точки использовались в качестве опорных для создания данной кривой. На полученном облаке точек можно построить огромное количество подобных кривых, из которых необходимо выбрать наиболее адекватные. Адекватными можно считать те кривые, для которых кривизна нормального сечения принимает максимальное и минимальное значения в заданном выше диапазоне. Так как функции построения подобных кривых не являются независимыми и они связаны между собой уравнениями, то семейство кривых, полностью удовлетворяющих условию, что следующая точка линии не должна выйти за сферу смещения, не будет многочисленным. В результате отбор кривых с максимальной степенью адекватности не представляет особого труда даже в ручном режиме. И это имеет своё преимущество, так как компьютер всё-таки не может полностью заменить человека в области нечёткой логики, он выдаёт на рассмотрение все возможные траектории (рис. 4).

Построение математической модели поверхности происходит аналогично построению кривых. Функции поверхности ограничиваются некоторыми значениями её параметров, и получается геометрическая информация о поверхности в точке, соответствующей данным значениям параметров.

Рис. 4
Семейство ортогональных NURBS-кривых внешней поверхности сосуда, имеющее максимальную степень адекватности

Если некоторая функция поверхности допускает выход значений параметров за область определения, то данный вариант поверхности отбрасывается и в дальнейшем рассмотрении не участвует.

Для построения поверхности на сетке, образованной двумя семействами кривых, были использованы составные поверхности Безье, получающиеся в результате стыковки отдельных поверхностей Безье, имеющих вдоль стыкуемых краев одинаковые степени. Данные поверхности ограничиваются контурами уже существующей поверхности сосуда и её параметрами. Им разрешается принимать значения только внутри области, ограниченной этими контурами.

Так как при поиске параметров линии пересечения в качестве границы можно использовать только габаритный прямоугольник внешнего контура сетки сосуда, то после построения линий пересечения поверхность проверялась на пересечение граничными контурами и усекалась этими контурами, сохранив только те части, которые лежат внутри реальных областей. После построения геометрии поверхности сосуда она текстурировалась вручную для придания более реалистичного внешнего вида (рис. 5).

Для оцифровки керамического сосуда и получения 3D-модели использовалось программное обеспечение Meshroom и задействовалась нейросеть U-Net с предобученными моделями. Для проведения работ по техническому вычислению при компьютерной «реставрации» стенки сосуда привлекался пакет прикладных программ MATHLAB версии R2020b. В качестве платформы 3D-визуализации применялся Autodesk 3dsMax 2020 Athena с системой рендеринга V-Ray Next.

Рис. 5

Результат компьютерной «реставрации» отсутствовавшей стенки сосуда

Заключение

Компьютерная «реставрация» пока ещё является довольно трудоёмким и несовершенным процессом с отсутствующей общей методикой и алгоритмами действий. В данной статье предложена для обсуждения логика решения одной из обозначившихся задач. Из неё можно исходить при создании математических моделей всего процесса создания виртуальной идеальной модели, к которой стремился автор-изготовитель, и учёте погрешностей его работы, как неизбежной постоянной составляющей несовершенства технологии, так и переменной составляющей – человеческого фактора. Представленный частный пример может стать основой для дальнейших исследований, связанных с изучением и презентацией керамической посуды пазырыкской культуры.

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ТРЁХМЕРНЫЕ МОДЕЛИ КАМЕННЫХ КРЕСТОВ КАК ВАРИАНТ ЭКСПОНИРОВАНИЯ ПАМЯТНИКОВ ИЗ «НЕДОСТУПНЫХ» МЕСТ

Историческая справка

Средневековые каменные кресты, в XII–XVI вв. получившие распространение на территории Новгородской земли как надгробия или культовые объекты, являются сложными для изучения памятниками. В настоящее время они находятся либо в довольно отдалённых сельских районах (преимущественно Ленинградской, Новгородской и Псковской областей), либо в фондах краеведческих и центральных музеев, в которые они стали поступать с целью сохранения уже в конце XIX в. Большинство памятников не опубликованы, а имеющиеся публикации носят разрозненный характер и в силу многочисленности объектов не содержат полных иллюстративных каталогов.

К началу XXI в. кресты из одного могильника или одной деревни могут частично сохраниться на месте, а частично оказаться в фондах трёх-четырёх различных музеев (Панченко, Фёдоров 2019).

Показательно проведенное нами сравнение изучаемых в настоящее время каменных крестов с данными прежних лет, полученными из публикаций, архивных источников, отчётов о работах археологических экспедиций, а также с материалами фондовых коллекций музеев. Оказалось, что к началу XXI в. изменилось и топографическое положение многих памятников – они были перемещены, или рассеяны по разным музеям, или просто исчезли с мест установки; также была нарушена и целостность музейных коллекций, собранных к началу XX в., зачастую с утратой атрибуции (Панченко 2014; Панченко, Карпов 2014; Николаева, Панченко 2017).

Рассмотрим для примера историю каменных крестов из д. Войносолово Кингисеппского района Ленинградской области, впервые упоминаемых в источниках в первой трети XVIII в. К середине XX в. около 25–30 каменных крестов находились в деревне в трёх скоплениях, рядом с одним из которых когда-то существовала часовня, и еще около 20 небольших крестов были обнаружены на деревенском кладбище, расположенном на средневековом могильнике (Панченко, Федоров 2019). Надпись на одном из массивных крестов, находившихся в деревне, позволяет датировать его XV в. В настоящее время крестов в деревне уже нет. Три из них установлены у Екатерининского собора в г. Кингисеппе (Ленинградская область), три были переданы (без атрибуции) в Государственный историко-архитектурный и природно-ландшафтный музей-заповедник «Изборск» (Псковская область), один обнаружен в д. Ястребино (Волосовский район Ленинградской области). Кресты на деревенском кладбище еще существуют, и даже постоянно выкапываются новые. Иногда они их оставляют на месте, но часто разбивают и выбрасывают в мусорные кучи. В 1998 г. здесь было зафиксировано 17 крестов, три из которых поступили в Церковно-археологический музей при Санкт-Петербургской Духовной Академии. В 2018 г. был составлен план кладбища с 20 крестами, и ещё четыре выброшенных креста были переданы в Эрмитаж (Панченко, Фёдоров 2017). Несколько памятников с кладбища, как нам удалось установить, перевезены в г. Гдов (Псковская область) и д. Беседа (Волосовский район Ленинградской области).

В 2019 г. студенты кафедры информационных технологий в креативных и культурных индустриях Гуманитарного института СФУ под руководством Н. О. Пикова впервые принимали участие в работах Археологической экспедиции Государственного Эрмитажа по изучению культовой архитектуры малых форм. Были созданы 3D-модели каменных крестов из д. Войносолово, находящиеся в фондах Эрмитажа (рис. 1–2).

Отметим, что этот вид работы позволяет представить объективное и точное изображение даже разбитого креста. Данные 3D-модели и описание крестов были опубликованы на сайте «Электронная энциклопедия Эрмитажа» (http://www.archaeoglobus.sfu-kras.ru/monument/kultovyj-kompleks-vojnosolovo/).

Кроме того, были созданы несколько 3D-моделей объектов, находящихся в поле (рис. 3) (http://www.archaeoglobus.sfu-kras.ru/monument/kultovyj-kompleks-smolegovitsy/).

Создание 3D-моделей с последующей их публикацией позволяет получить качественные изображения труднодоступных памятников, необходимые для дальнейшей научной работы по изучению каменных крестов. Такие публикации позволят реконструировать в виртуальном пространстве скопления крестов из одной деревни, что важно для воссоздания исторического и культурного ландшафта. В 2021 г. нами создаются 3D-модели еще 20 памятников. Так, перспективным видится применение метода компьютерной реставрации разбитых каменных крестов для восстановления их первоначального вида. Мы надеемся продолжить работы в данном направлении.

Методы исследования

В ходе работы применялась технология фотограмметрии – процесс создания 3D-модели на основе изображений объекта, сфотографированного с разных углов. Съёмка каменных крестов производилась в камеральных и полевых условиях с помощью следующего оборудования: фотоаппарат Canon 5DsR и объектив Canon 24–70 mm.

Сценарий съёмки в камеральных условиях состоял из двух этапов: первый включал съёмку вращающегося вокруг своей оси объекта с трёх позиций фотоаппарата – 0°, 40°, 80°, второй этап – аналогичен первому, однако объект был перевёрнут на 180°.

Сценарий съёмки в полевых условиях также состоял из двух этапов: на первом была зафиксирована общая геометрия объекта, для этого он был сфотографирован вокруг не менее чем с трёх позиций– приблизительно 0°, 40° и 80°. На втором этапе внимание уделялось ранее незафиксированным и особо значимым областям объекта.

В обоих случаях фотографии делались с большим перекрытием соседних кадров, равным в среднем 50 %, поэтому на одну позицию фотоаппарата приходилось около 30 снимков, а по завершении всей съёмки – около 180. Однако в полевых условиях количество снимков зависело от размера и общей геометрии объекта, поэтому в результате получалось около 300–500 снимков.

Рис. 1
3D-модель креста с надписями (АСЗ-1)

Рис. 2
3D-модель разбитого креста (АСЗ-4)

Рис. 3
3D-модель большого креста из д. Старые Смолеговицы

Для создания 3D-модели на основе фотоизображений используется программное обеспечение Agisoft Metashape. Принцип создания заключается в том, что на каждом изображении отыскиваются общие точки, а по ним определяются пространственные координаты, в результате чего создаётся облако точек – совокупность всех пространственных координат фотографируемого объекта (рис. 4).

На основе облака точек создаётся полигональная сетка – совокупность вершин, рёбер и граней, которые определяют форму 3D-модели (рис. 5).

По завершении для назначения цвета определяется соответствие между пикселями на фотоизображении и полигонами, в результате чего образуется текстура 3D-модели (рис. 6).

Таким образом, в результате работы была произведена съёмка 33 объектов в камеральных и полевых условиях, и на основе их изображений созданы 3D-модели (https://skfb.ly/ooRWo).

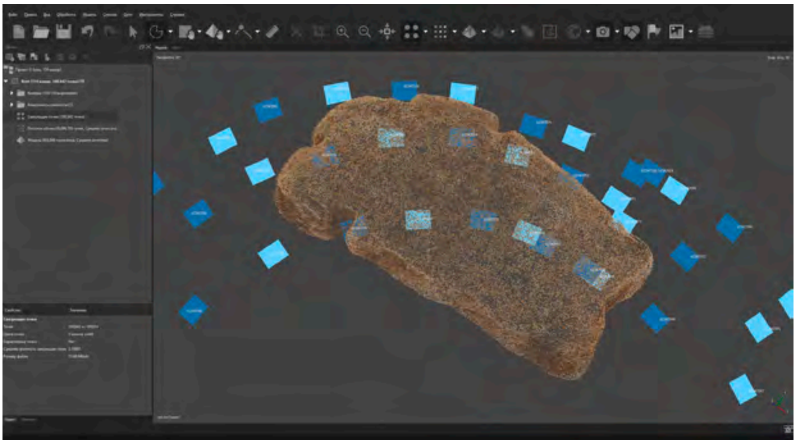

Рис. 4
Облако точек

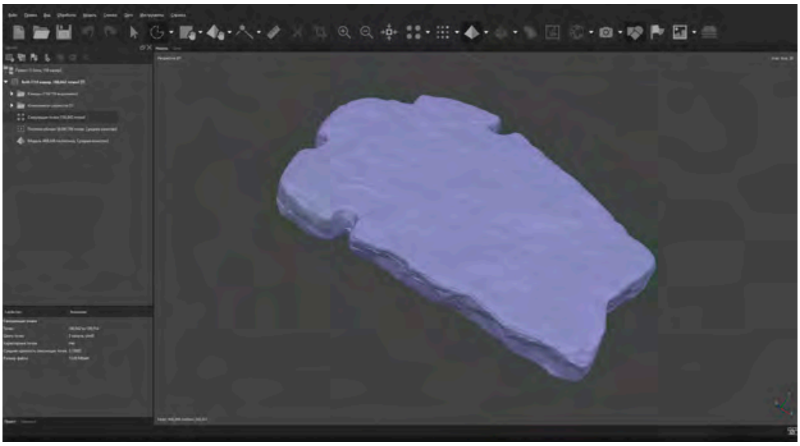

Рис. 5
Полигональная 3D-модель

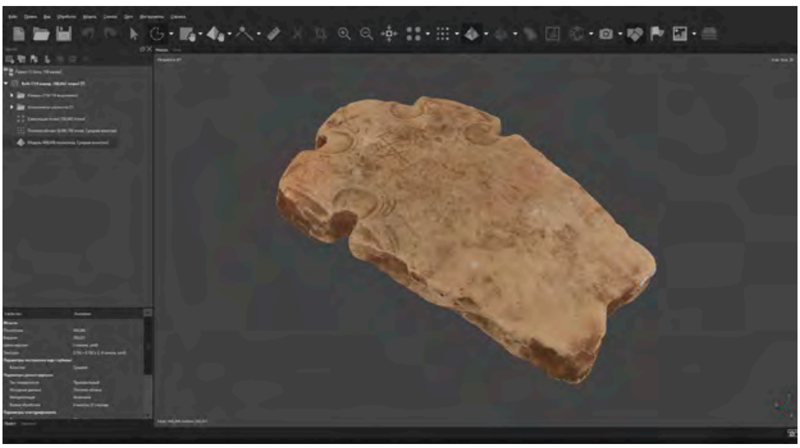

Рис. 6
Текстурированная 3D-модель

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SHIFTING GROUNDS: THE ARCHAEOLOGICAL PRACTICE IN THE AGE OF DIGITAL TECHNOLOGY

Introduction

In the last decade, 3D visualisation has seen a strong diffusion in the cultural heritage sector. The development of more efficient computers, the distribution of friendly user interfaces, and the spread of new sensors for recording and visualising information were pivotal for exploring 3D visualisation technology to support advanced interaction and promote new investigation methods. Since the early 1990s, 3D visualisation was conceived as a dynamic tool for increasing the perception of the archaeological material (Reilly 1991), and 3D models were considered an effective solution for addressing complex questions and revising different hypotheses (Renfrew 1997).

Despite the possibilities offered by 3D visualisation, the third dimension was mainly used to provide the general public with explicative and more realistic pictures of the past. Most of the papers produced at the beginning of the 2000s focused on public engagement and technological innovation with minimal impact on theory, methods and knowledge production (Hermon 2008, 37).

More recently, scholars started conducting experiments for testing the use of 3D visualisation in support of research and analysis. Visualising for understanding was a better practice, and for this reason, several researchers started using 3D models to review and clarify the relationships among the fragmented archaeological pieces of evidence scattered across time and space.

3D visualisation was more and more conceived as a tool for observing rather than presenting (Frischer, Dakouri-Hild 2008), and the diffusion of friendly user interfaces and affordable visualisation technology triggered an exciting experimentation phase. An example of this approach was developed within the frame of the archaeological investigation conducted by Frischer and Fillwalk in the Campus Martius in Rome, where 3D computer simulations were used to shed light on the structural and symbolic relationship among different monuments at the time of their foundation (Frischer, Fillwalk 2013).

The spread of 3D recording technologies such as Laser Scanning and Image-Based 3D Modelling represented another significant step for the diffusion of 3D visualisation within the archaeological practice. These new documentation methods had significant implications on how archaeological information is recorded and managed (Roosevelt et al. 2015), and the possibilities of including these techniques during the field investigation provide archaeologists with the opportunity to assess the capacity of 3D visualisation to go beyond the sphere of discovery (Callieri et al. 2011; Edgeworth 2014; Berggren et al. 2015; Taylor et al. 2018).

Today, the possibility (1) to use multiple types of devices, (2) to choose among various sets of 3D models and (3) to engage with sensors capable of catching information beyond the visible spectrum provides the prerequisite for testing new investigation strategies and identifying new information. However, the advantages of adopting 3D visualisation and recording systems in support of archaeological field practice are not only related to the possibility of creating virtual replicas of the evidence encountered during the investigation but rather on the possibility of bridging the physical and the virtual dimensions for assessing new research strategies and identifying novel relations. Archaeological investigation environments consist of elements that expand far beyond their shape (Valente et al. 2017), and 3D visualisation can highlight and link both tangible and intangible aspects of the information.

3D Visualization and Archaeological Field Practice

Among the different solutions available for assessing the potentials of 3D visualisation within the archaeological practice, 3D Geographic Information Systems were successfully adopted in several projects to review the excavation process (Opitz, Nowlin 2012; Berggren et al. 2015; Roosevelt et al. 2015; Dell'Unto et al. 2015), to assess the volumetric relation between the strata (Lieberwirth 2008; Landeschi et al. 2019), to include the work of specialists within a broader investigation (Wilhelmson, Dell'Unto 2015) and to support visibility and architectural studies (Landeschi et al. 2015; Polig 2017).

Within the Lund University Digital Archaeology Laboratory DARKLab (www.darklab.lu.se), we have been testing the use of 3D GIS platforms in the frame of several projects to answer research questions considered too difficult (or sometimes impossible) to assess in a 2D environment.

Among the different case studies developed, the archaeological site of Stora Förvar – recently investigated within the frame of the research project "the pioneer settlements of Gotland" – represents an excellent example of how 3D GIS platforms (and 3D visualisation in general) can be employed for creating multi-dimensional representations of the space to address complex research questions.

In this specific case, it was possible to merge in the same virtual environment datasets collected by different archaeologists across a period of almost 200 years. The site was initially excavated between 1888 and 1893 by the archaeologists Lars Kolmodin and Hjalmar Stolpe. Part of the documentation was published in 1940 (several years after the end of the field activities), and more recently (in 2013), a new excavation was carried out for assessing and studying the presence of cultural layers that could provide further information on the temporal sequence of activities which took place on-site (Apel, Storå, Landeschi 2015; Apel, Storå 2017). This also represented a good occasion for designing a 3D visualisation environment capable of combining the information retrieved during the excavation in spatial relation with the available archaeological records collected during previous investigations. For this reason, a Phase-Based Laser Scanner was employed for producing an accurate 3D description of the cave where the investigation campaigns took place (Lundström 2016; Landeschi et al. 2019).

By combining the information visible on the graphic documentation produced during the 19th century with the 3D surface model generated using the laser scanner, it was possible to employ the 3D GIS for reconstructing the sequence of layers removed during the excavation (fig.1, A). This operation allowed simulating the spatial relations between the arbitrary layers and the artefacts retrieved at the time of the excavation/s (Landeschi et al. 2019). The possibility of using the 3D GIS to include legacy data within the 3D visualisation system allowed reconstructing the relationships between artefacts and layers (fig. 1, B). The interpolation of such datasets within a 3D spatial environment allowed the generation of density maps for displaying the distribution of different categories of artefacts in the virtual cave bringing important indications concerning the use of the site during the Mesolithic (Landeschi et al. 2019, 2817).

This experiment demonstrated how 3D visualisation technology could be a crucial asset when dealing with datasets collected using different methodological approaches. In particular, the possibility of reusing legacy data for virtually simulating the space where the investigation was conducted represented an enormous advantage. This experiment shed light on the capacity of 3D visualisation to bridge the physical with the digital reality providing researchers with the possibility of operating simultaneously on multiple grounds.

Another exciting aspect to consider relies on the possibility of using 3D visualisation technology directly in the field (Dell'Unto et al. 2017; Taylor et al. 2018). Using a tablet PC on-site for managing and visualising the information uploaded in the 3D visualisation system makes it possible to verify the hypothesis defined in the virtual dimension against the evidence encountered during the investigation (and vice versa).

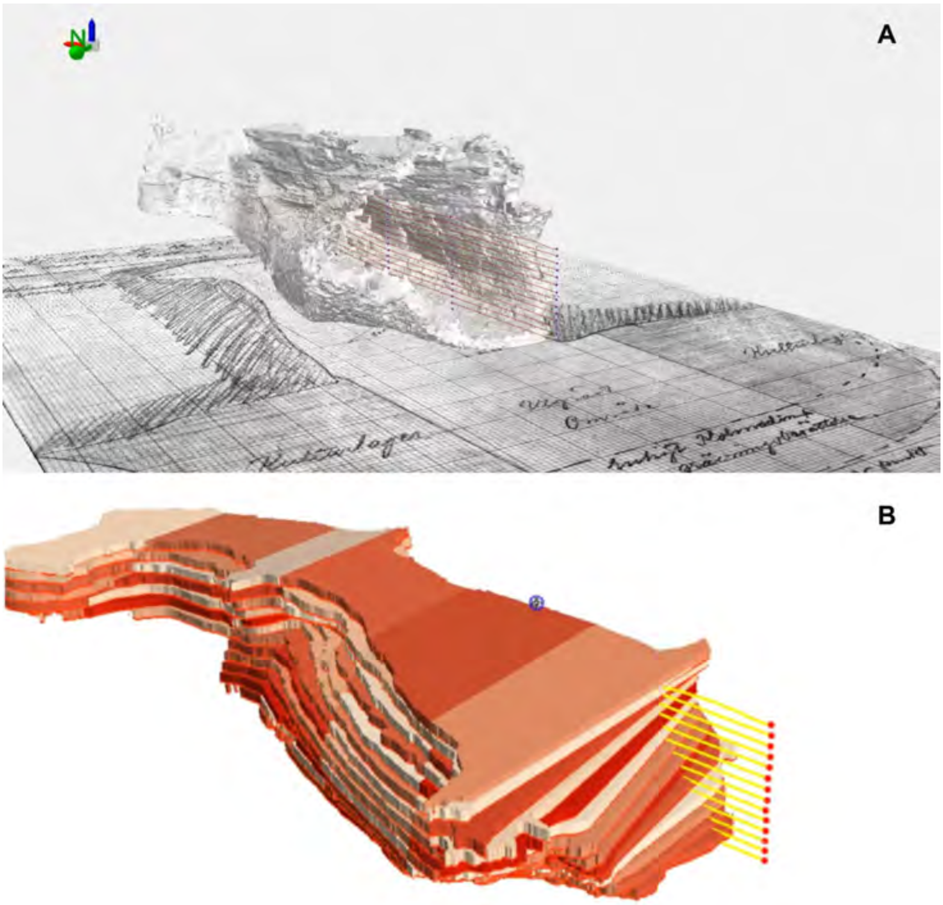

Fig. 1

The image displays the archaeological site of Stora Förvar visualized in the 3D GIS. On the upper part of the image (A), the 3D surface model of the cave is displayed in spatial relation with the analogue documentation. In the lower part of the image (B), the 3D volumetric layers are reconstructed using the documentation produced during the 19th century. 3D GIS visualization made by Giacomo Landeschi, the 3D surface model produced by Stefan Lindgren and Victor Lundström

This practice has a significant impact on the way the records are collected and used in the field, and it is in line with the idea that the archaeological records should be the result of a direct and non-mediated experience (e.g. Powlesland 2016).

By keeping separate the digital and the physical dimensions, we reduce the intellectual engagement with the material being investigated, generating interpretations that do not include all aspects of the investigation. This reinforces the idea that the virtual (3D) space should not be considered an alternative method but as a central practice for understanding the past.

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ACTING IN DIGITAL CULTURAL HERITAGE APPLICATIONS

Introduction

Digital technologies offer a new way to communicate and experience cultural heritage. It is now becoming possible to virtually recreate the original appearance of cultural monuments and enable the users to take virtual walks exploring interactive 3D models of objects preserved only in remains. Virtual Reality (VR) is a technology that transfers the users to a different place and time through devices called Head Mounted Displays (HMD) and enables a total immersion in another reality.

But even the most photorealistic virtual reconstruction is not attractive enough without people (Rizvić 2017). Virtual reconstructions populated with 3D models of inhabitants bring better experience to the visitors, but it is still not completely immersive. Our experience shows that the maximum level of immersion is achieved when real actors are added inside virtual reconstructions, telling stories in the roles of historical characters (Rizvić et al. 2019). In this paper, we will present this methodology from a different perspective: through the experience of the actors. We will show which acting methods changed when applied in Virtual Reality and which have remained the same. The main research hypothesis is that real actors add to immersion and edutainment of virtual cultural heritage applications and we will confirm it through the actor's experience and the experiences of our users.

The paper is organised in the following way: the Background section gives an overview of acting through the history and state of the art in Virtual Reality projects involving actors; The Case studies section briefly describes the projects we developed, Actor's experience presents the actor's point of view and the challenges she encountered playing in Virtual Reality; the User experience section proves our hypothesis through user experience evaluation studies, and in the end we present our conclusions.

Background

Acting through history

Acting in VR is a relatively new experience for actors, so we cannot claim with certainty what acting techniques, systems, and models we could implement in this medium. Throughout the rich history of the art of acting, there have been numerous attempts to define the process by which actors create their own role, to analyse and develop a psychological and physical approach to this process, but even today we can say that acting is a secret still being revealed. In an attempt to create a system of acting in VR, it is useful to remind ourselves of all the ideas about acting produced throughout history, mainly practice gave birth to theory, and theory was validated in practice through different experiments and specific experiences.

Acting theories have existed ever since Plato and Aristotle. Plato believed that acting feeds passion instead of controlling it, whereas Aristotle believed that acting brings catharsis showing us not what is happening, but what could happen, not the man that he is, but the man he could be. As early as 685 BC, in his poem Ars Poetica, Horatio predicted the dominant path in European acting: realism (truth and religion). Christianity condemned drama and acting. John the Baptist cursed those who go to theatres, and Augustine of Hippo believed that love of theatre was pure madness. The following centuries left no written traces of the development of the art of acting until Averroes, who translated Aristotle's Poetics in the 12th century and sparked interest in theatre. The medieval theatre mostly displayed liturgical drama, although at the same time folk comedy was being developed in the streets, fairs, and squares. As for acting, it experienced the next important phase of its development through Commedia dell'arte, which introduced masks and type characters. The 15th and 16th centuries introduced serious theoretical texts and polemics about whether acting was the art of reality or the reality itself. This is a dilemma that has existed ever since Aristotle – whether actors represent or live the part they play, what means they use to represent the part, to what extent they live the part or identify with the part they play.

Miguel de Cervantes stated that the function of drama and theatre was to be the mirror of nature and the image of truth. Religious conservatism of sixteenth-century England criticized acting for being a lie, and lying is a sin. Nevertheless, in his tragedies and comedies, Shakespeare spoke of the importance of theatre and defined the main aspects of acting technique in his famous monologue in Hamlet (Hamlet's speech to the actors) in which he talks about mimesis, plots, speech technique, movement, control, taste, etc. In the comedy A Midsummer Night's Dream, he emphasises the primordial human need for acting and its social function; he talks about communication with the audience, the life of characters and distance, genres…

In the 17th century, in his comedies, Moliere speaks of the principles of acting, whereas in the 18th century, Diderot wrote in the Paradox of the Actor that actors play a vital role in society and deserve respect, entering into a polemic with great actress Gabrielle Réjane who advocated complete identification with a character, whereas Diderot believed in detailed preparation and the technical aspect of the art of acting, considering it equally important to the actor's feelings. At the same time, serious texts about the art of acting are written in England, and actor and director David Garrick believes that acting is the art of creation, the actor does not imitate but carefully observes and creates the role to perfection based on his understanding.

All the major philosophers of the 18th and 19th century Germany wrote about acting. In the Hamburg Dramaturgy, Lessing wrote that actors' technique is just as important as their feelings. Schopenhauer noted that actors cannot disavow their personality, they have to be intelligent and experienced enough to understand the character and have the ability to show it on the stage.

Romanticism gave priority to emotions, and the entire 19th century was marked by the contemplation of what is the priority – reason or emotions. In his essay/book Mask or Faces, William Archer believes that such a dilemma is unnecessary because willful actions cannot be separated from emotions, intellect and emotions always go hand in hand, in parallel. Belinsky and Grigoryev in Russia wrote that actors are not ordinary performers, they are wizards of deep spirituality and unbridled imagination. The naturalism of the 19th century returns acting and actors to simple gestures and natural movements displaying the man in his everyday life.

Symbolism attempted to replace actors with masks, statues, shadows, dolls, so that the form becomes more important than the content. Meyerhold believed that theatre should give up on realism. However, the Russian symbolists became more interested in the work of Konstantin Sergeyevich Stanislavski who set the foundations of modern acting and made the first system of acting based on theory and practice. During the 20th century, the art of acting underwent perhaps the biggest transformation, given the numerous theories and practices that existed. The most influential theatre practitioners – Stanislavski, Brecht, and Artaud – made an immense contribution to theory, as did many others such as Grotowski, Michael Chekhov, Sanford Meisner, Beckett, Ionesko, Viola Spolin, Pina Bausch, Robert Wilson… The theories and practices of the 20th century brought new challenges for actors; they gained experiences in synthetic theatre, theatre of the absurd, political theatre, dance theatre, theatre of attractions, biomechanics, ritual theatre, dialectical theatre… In 1929, Stanislavski wrote his famous text The Art of Actor and Director, and subsequently numerous books on theory and practice of acting, thus setting the foundations of modern theatre acting and film acting of the future. His main struggle in theatre was the struggle for realism, for life through the art of experience, and we can assert that his system "has in itself everything that comprises an integral, sufficiently closed system, which is at the same time open enough to produce or subsequently receive a whole series of new ideas…"(Stjepanović 2005, 131). Stanislavski's system became the foundation for the development of the realistic approach to acting that was developed in the famous Actors Studio in New York where Harold Clurman, Stella Adler, and Lee Strasberg produced generations of actors who developed the system of approach to film acting that we cultivate today.

At the end of this short overview of ideas in acting through centuries, we ask ourselves whether it is possible to create a certain system of acting in VR in the future that will have its own strict rules and will serve as a guide for actors in a medium that most certainly awaits them? Creating and expressing reality in a VR film is a new challenge posed to actors of today.

Virtual Reality applications with actors

Adventure game Phantasmagoria (Kurlan) by Sierra in 1995 is one of the first applications using actors in Virtual Environments (VE). The main characters were filmed in front of a green screen with pre-rendered backgrounds. At that time, it was a good solution for graphics in computer games. In digital cultural heritage, the Livia's Villa Reloaded project is significant (Pietroni, Forlani, Rufa 2015). In this project actors are telling stories about the life in the Villa of the wife of the Roman emperor Augustus. The application is implemented as a Kinect application that uses gestures, online WebGL application and application for HMD, and uses interactive digital storytelling methodology. Samuel Beckett in VR (O'Dwyer et al. 2018) is an interactive VR narrative of Samuel Beckett's theatrical text Play. Actors are filmed in front of a green screen using free-viewpoint video (FVV) and then the VE is added as a background.

A valuable analysis is presented in (Elmezeny, Edenhofer, Wimmer 2018) where two dimensions of immersion in 360-degree videos – narrative and technical – are considered. The user experience evaluation with a comparison between 360-degree videos and traditional linear videos has been conducted. The authors state that 360-degree videos are still mostly narrative-driven, and cues are essential for directing the user's attention. The cues need to be communicated to actors in order to secure the users' attention in the right direction. We support this statement and implement it in our projects.

Fig. 1
Filming the actor in White Bastion project. Photo: S. Rizvić

Case studies

Sarajevo Graphics Group research laboratory from the Faculty of Electrical Engineering, University of Sarajevo, Bosnia and Herzegovina, has been creating digital cultural heritage applications since 2005. Here we will mention those that use the actors and describe how our experience has been introducing changes and improvements in every next project.

The 4D Virtual Reconstruction of White Bastion Fortress (Rizvić et al. 2016) is a digital presentation of the fortress in Sarajevo built in the medieval period. The archaeological excavations also contain findings from the Ottoman and Austro-Hungarian periods. We presented the history of this fortress through an interactive digital storytelling application combining 6 virtual models of the object from all 3 historical periods with narration and reconstructions of artefacts found on the site. The actor-narrator plays the role of an eternal soldier from the fortress, changing uniforms according to historical periods (fig. 1). The actor is recorded on the site and 3D reconstructions of the fortress are added behind him using digital compositing. The final format of digital stories is HD video. The stories are added in the WebGL application created in Unity 3D (4D Virtual Reconstruction of White Bastion Fortress Application 2016). Modelling of the fortress was done in Cinema 4D.

Within the H2020 iMARECULTURE project (Skarlatos et al. 2016), which aimed to present underwater cultural heritage using digital technologies, we first created a pilot interactive digital storytelling application about one of the oldest shipwrecks in human history, known as the Kyrenia shipwreck (Rizvić et al. 2017b). In this project we created 6 stories, 3 about technical characteristics of the ship and its assumed sailing route and 3 about the life of sailors and their sad destiny. For the technical stories we recorded the actor on the green screen and superimposed him in the computer animation, and in the remaining stories the actress playing the role of the captain's wife was recorded in exteriors at the seaside (fig. 2). The final format of these stories was HD video, and the whole application was implemented as a web site (Kyrenia Interactive Digital Story 2017).

For the iMARECULTURE project we also created storytelling for 3 selected underwater sites: Baia in Italy, Mazotos in Cyprus and Xlendi in Malta. In Baia storytelling we created 360° video stories as composites from actors recorded on green screen and 360° renders of virtual reconstructions of a Roman villa and the village streets. Baia was a luxurious resort of Roman aristocracy where they used to spend their summer holidays. It is located close to Naples, Italy. Today half of the city remains underwater and the other half is inside the archaeological park. The sunken part that can be visited only by divers today can be explored through our Virtual Reality application. In Baia storytelling the actors recreated an episode of the town's life where a rich aristocrat is buying a statue from a local sculptor (fig. 3). The final format of digital stories is a 360° video embedded in the Dry Visits Unity VR application.

Mazotos is a shipwreck site close to the village Mazotos in Cyprus. It is assumed that the sunken ship was transporting goods placed in amphoras, so we have created a digital story about transportation means in the classical Greek period. The actor-narrator is recorded on green screen and superimposed onto an animated background displaying various information from his narration (fig. 4). The final format of the story is a 360° video, embedded in the Dry Visits Unity VR application.

Fig. 2
Actors in Kyrenia interactive digital story. Photo: S. Rizvić

Fig. 3
Actors in Baia storytelling. Photo: S. Rizvić

Fig. 4
Actor in transport amphorae story, iMARECULTURE project. Photo: S. Rizvić

During the dry visit to Xlendi we present a 112-meter deep site of a shipwreck where a Phoenician ship has sunk close to the village of Xlendi in Gozo, Malta. The actor recorded on green screen and superimposed over computer-generated images tells the story of the wine trade in the classical Greek period (fig. 5), as it is assumed that the sunken ship was transporting wine. This story is exported in HD video embedded in the Dry Visits Unity VR application.

Fig. 5
Actor in wine trade story, iMARECULTURE project. Photo: S. Rizvić

Fig. 6
Actress playing different historical characters,
Roman Heritage in the Balkans project. Photo: S. Rizvić

Another project where we recreated life in the past through digital storytelling with actors is Roman Heritage in the Balkans (Roman Heritage in the Balkans Project 2020). We recorded in a 360° video format the selected sites with remains from the Roman period in Serbia, Montenegro, Albania and Bosnia and Herzegovina and created a Virtual Reality application presenting each site in form of the 360° VR reconstruction of its original appearance superimposed over the video of the remains (fig. 6). In these stories the actress had to be aware of the virtual environment in which she would be added and to look and play in the right direction in accordance with the virtual background. The actress played 12 different characters from the history of the selected sites. She was recorded on green screen and added to the background in Adobe After Effects. The stories were rendered as VR videos and embedded in the Unity VR application available in local museums.

In the Old crafts Virtual Museum (Old Crafts Virtual Museum Project 2020) (fig. 7) and Underground project (Underground Virtual Exhibition 2021) (fig. 8), the actors recorded on green screen were added directly to the Unity virtual environment, without superimposing or rendering in a video format. In this process, we encountered the challenge of "floating", as the viewer did not have the feeling that the actor belongs in the virtual environment. We overcame this problem by adding him to the 3D geometry instead of rendering the 360° image used as a background.

In the Battle of Neretva VR we recreated one of the most important WWII battles in Bosnia and Herzegovina, which took place in Jablanica. Adding a VR application (Battle on Neretva VR 2020) to the Battle Museum exhibition, we created an educational game where the user is tasked to destroy the bridge, take down enemy airplanes and transport

Fig. 7
Old crafts Virtual Museum. Photo: S. Rizvić

Fig. 8
Actor added to the virtual model in Unity 3D, Underground project. Photo: S. Rizvić

a wounded comrade across the river, as it happened in the historical event. Here we recorded the actors in 360° video and combined those videos in the Unity 3D application, together with a game play animation (fig. 9). In this storytelling we were facing all the challenges of filming in VR, setting up not yet established film grammar rules and procedures for this new media format.

Actor's experience

The primary function of acting is to communicate thoughts and emotions to the audience and this thesis is the foundation of everything we need to know about film and theatre. However, most actors come from theatre acting tradition, which makes the challenges of film acting even greater. Sir Laurence Olivier used to say: "It took me many years to learn to film-act" (Barr 1997, 6) and when Sir John Gielgud was asked what was the most difficult aspect of film acting, he replied: "Making it simple!" (Barr 1997, 6)/

Film acting has undergone an interesting path from big gestures to simplicity. In silent films, due to the lack of sound, directors and actors needed to overemphasize gestures and facial expressions so the audience could follow the story. The introduction of sound made big changes because silent-film actors faced the problem of adjusting to a new situation; many of them gave up, and producers and directors reached out to theatre actors in search of a more realistic performance.

In theatre, actors must communicate with people sitting in the back row as well; gestures are larger, the physical aspect of acting must be visible enough because details can often be lost in space. While on film the audience is in the camera, each physical action of the actors is enlarged and focused on their faces. By the end of the 1930s, numerous film stars appeared (James Stewart, John Wayne, Katharine Hepburn, Henry Fonda, Clark Gable, Spencer Tracy…), actors who tried to reconcile the two worlds and get closer to common people in order to make the audience's identification easier. Alongside the film, there is The Group Theatre in 1930s New York with Lee Strasberg, Elia Kazan, Stella Adler… which gave birth to the Actors Studio. A more naturalistic style was dominant in the 1940s when Marlon Brando appeared on film and set new standards of film acting. The 1950s brought another revolution – television. Actors came into viewers' homes, big close-ups became common so actors had to keep their performance under control of simplicity. Actors had to follow and adjust their acting to new technological achievements.

When thinking of VR, we usually focus on the technical aspect of this experience. We pay less attention to the importance of the art of acting and the contribution of actors to this

Fig. 9
Filming the actors in 360 video, Battle on Neretva VR. Photo: S. Rizvić

new technology. The role of actors in VR has not been researched or defined sufficiently, because it is a relatively new experience and not part of formal education, and for good reason. Our past experiences suggest that actors must certainly pay attention to the means of acting used in the green screen and the VR film because they are different.

In his book "Acting for the Camera", Tony Barr defines a good actor: "I believe good actor is 1. one who can articulate for the audience what the material is about; 2. one who can interest the audience sufficiently to make them want to stay and watch the performance; and 3. perhaps most important, one who is able to move the audience." (Barr 1997, 288) When watching a film, we suppose that everything we need to know is within a frame, everything outside the frame is irrelevant and meaningless. However, with the arrival of VR technology, actors are faced with numerous new questions when acting is concerned.

Actors in a 360° video must primarily think about what a viewer could see. Unlike filming a 2D film in frames, in a VR film, actors are found within a frame at every moment, they cannot hide or leave the frame, their focus must be continuous. In this case, emotional engagement must always be at the same level, because we never know whether the viewer will choose to look at the actor in close-up all the time. Actors must also be aware at any moment and control their physical adjustment to the role, they cannot relax, the body must always be alive and present. If in any key scene the viewer decides to focus on the actor's hand or mouth, the entire body must play the role. Everything the actor does can be seen by the viewer at a certain point. Such a way of acting demands supreme concentration as well as the ability to maintain an emotional intensity through the shooting. Actors must be trained in a classical sense of the continuity of role demanded by theatre, as well as expressiveness and emotionality demanded by film acting.

VR film represents life perhaps more intensely than theatre and film because the viewer can see actors in their entirety at every moment. If there are many actors in a VR scene, the director must make sure that all actors act with the same intensity, obviously with the difference in roles, but it is very important that they are aware of the medium they are acting in and that they maintain the truthfulness of the world they are creating together. Another interesting fact of VR acting is that there are no small and big roles in a scene with many actors, all roles are important and big, equally important are those who lead the scene and those who may not say even a word and just sit around. Such characters might be called extras in a film, but in VR they can become one of the key characters if the viewer decides to focus on that particular actor in the scene.

The VR headset used by viewers gives them the freedom to focus on any point within the 360-degree image and this viewer position has more in common with the theatre than with the film. The viewer is the one choosing the point of focus, it is not suggested by the film cut or editing, the viewer can create his own story from what is being offered. The viewer does not need to watch the actor who is talking, he can choose to look at what's on the table or what the weather is like by looking through the window or he can focus on a seemingly meaningless detail. The film director and editor decide where to direct the viewer's attention, they lead the viewer to what they want to be seen. There is no foreground, middleground, background, everyone can be in the foreground regardless of having a line in the scene or not, everyone must be in character all the time.

It is also very important to distinguish acting in the VR film from acting in front of the green screen. In the latter case, acting must be very reduced. The story is certainly in the foreground, but the body and gestures must be very controlled. Actors must always be aware that they are just a guide through the world that will be technically processed by graphic designers and that is how they tell a story. If actors decide to make a certain movement, they must cooperate with the director or graphic designer in order to direct that movement to the focus of the story. While the VR film offers certain freedom and continuous presence of actors, the freedom in front of the green screen is nevertheless limited to actors entirely serving the world that is digitally made by designers.

We can say that VR acting is close to theatre acting where actors are always aware of being entirely watched. While in the film actors can be distributed depending on the shot, in VR film actors must be ready to combine the two worlds – theatre (in terms of physical adjustments) and film (in terms of emotional intensity needed for film acting). We believe that acting using VR technology will get its own system and rules, but past experiences show that the combination of film and theatre experience is the most useful approach.

Acting using VR technology will most certainly pose a challenge for actors in the future, but the art of acting will surmount the challenges of new technologies like it had survived and adjusted to all the technical achievements in its rich millennial history.

User experience

The most credible method to evaluate the quality of digital heritage applications is the user experience. For every mentioned project we performed the user experience evaluation studies using qualitative and quantitative methodology. Here we will present just a short overview of results we obtained through those studies.

For the White Bastion project, most of the users reported feeling more engaged and paying more attention to interactive presentations of cultural heritage. They appreciated the possibility to explore the VEs which they could not do in a movie. They like the combination of digital stories and models because "models are described by stories and can display the information from stories". They stated that the actor added an emotional dimension to the presentation.

In the Kyrenia project the user experience evaluation conducted shows that we achieved a high level of edutainment, as users state that they learned about the ship in an attractive and amusing way (Rizvić et al. 2017b). The users showed a high level of empathy towards the wife of the captain, becoming emotionally involved in her tragic story.

Dry visit application presenting underwater sites selected by the iMARECULTURE project in VR was also appreciated by the users. Aside from gaining the opportunity to visit the sites that were only accessible to divers, they expressed satisfaction with storytelling claiming that the actors recreated life in the past, which they got to experience through Virtual Reality (Škola et al. 2020).

The users also enjoyed the performance of the actress in the Roman Heritage in the Balkans project, particularly the different roles she was playing, wearing different costumes and connecting the history of selected sites with their virtual reconstructions through characters in the stories.

The actor in the Old crafts Virtual Museum, according to the users' opinions, revived the forgotten craftsmen through storytelling, reciting funny verses in the form of old folk songs. In the Battle on Neretva the actor was perceived as the partisan commander and the users followed his directions through the gameplay. The most favorite moment for the users was when, at the end of the game play, comrade Tito appeared to congratulate them on the successfully completed mission. In the Underground project, the actor successfully conveyed to the audience the tragic destiny of dissidents and the emotion of their testimonies.

What all these results have in common is that the users very much appreciate storytelling performed by actors and enjoy identifying with the roles they play. This gives us a great opportunity to recreate cultural heritage in Virtual Reality and realise the eternal dream of traveling through time to the past.

Conclusions

In this paper, we have presented how cultural heritage can be recreated and preserved using digital technologies. In the projects mentioned, actors are either recorded on green screen or filmed with a 360° camera and added to Virtual Reality applications. We offer insights of the production coordinator about VR technology and interactive digital storytelling methodology (Rizvić et al. 2017a), as well as insights of the actress involved in the production.

We present which acting methods apply in VR and which need to be adjusted. As VR videos and applications are still a new media without defined rules of film language and production, we consider our experience as pioneering and offer it to researchers as references for their future projects.

We can conclude that digital heritage applications are interdisciplinary projects involving different professionals, such as archaeologists, historians, writers, film and visual artists, music authors, sound and production designers and computer scientists. Each of these professionals adjusts to the new media of Virtual Reality. The quality of that adjustment brings success to the created application.

We believe that Virtual Reality production is the media of the future. Its potential in presenting cultural heritage can bring heritage closer to the people and draw attention to the important lessons from the past.

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ПЕРСПЕКТИВЫ ПРИМЕНЕНИЯ ИНСТРУМЕНТОВ УПРАВЛЕНИЯ VR/AR-КОНТЕНТОМ В АРХЕОЛОГИИ

С развитием технологий виртуальной и дополненной реальности, информационно-телекоммуникационных сетей передачи данных, систем хранения данных в частности и информационных технологий в целом у исследователей разных областей появилось много возможностей по представлению своих исследований и созданию обучающих материалов. Основными элементами, которые используются при создании VR/AR-контента являются 3D-модели, текстуры, анимации. Создание трёхмерного археологического контента (создание 3D-моделей) научным сообществом начато довольно давно (Salvadori 2003). С развитием технологий 3D-сканирования, ростом и доступностью вычислительных мощностей археологи всё чаще стали использовать технологии 3D-сканирования (Зайцева 2014, 300–302) и фотограмметрии (Старовойтов, Лунева 2013, 16–18), как при камеральных работах, так и в полевых условиях. Отдельно можно выделить виртуальные реконструкции различных поселений (Patay-Horváth 2014, 12–22), событий, исторических механизмов, которые создают учёные путём компьютерного моделирования для различных задач.

Всё вышеперечисленное, по сути, можно рассматривать с точки зрения трёхмерного контента (включая текстуры, анимации и пр.), который используется с различными целями, хранится у исследователей на компьютерах, представляется в музеях на выставках и т. п. Но с развитием технологий, потребительской доступности очков виртуальной реальности для широких масс населения возникают задачи управления данным контентом, в том числе и для VR/AR-систем.

VR/AR-технологии позволяют внедрять различные интерактивные возможности, геймификацию, контролировать обучение студентов профильных специальностей или других лиц в рамках образовательных кружков и курсов. Однако создание различных виртуальных элементов с объединением в единую логическую систему является нетривиальной задачей для неподготовленного специалиста. Конечно, существуют платформы для реализации VR/AR-приложений, такие как Google Tilt

Brush, Gravity Sketch, Oculus Medium, A-Frame, Varwin и др., но они требуют специфичных навыков, у многих отсутствует система визуального программирования, и ни у одной системы или фреймворка нет интеграций с археологическими и образовательными системами, такими как 3Dhop (Vecchione, Lureau, Callieri 2019, 483–486) и Moodle. Ввиду вышеперечисленного в Иркутском национальном исследовательском техническом университете была начата разработка простого в использовании конструктора, который может интегрироваться в разнообразные системы и иметь все необходимые функции и достаточное количество шаблонов, для решения типовых задач неподготовленными к тонкостям разработки VR/AR-контента пользователями, в основном преподавателями, разработчиками курсов, исследователями, музейными сотрудниками.

Учитывая то, что разрабатываемая система предполагает использование её широким кругом специалистов, она должна иметь поддержку визуального программирования, иметь возможность интегрироваться в применяемые археологами и историками системы, быть дружественной к конечному пользователю в отличие от других представленных аналогов. Несмотря на то, что на рынке информационных продуктов есть готовые инструменты для создания VR-симуляций и интерактивных обучающих приложений, не существует универсального подхода к построению конечных решений или готовых образовательных продуктов. В связи с этим пока невозможно развивать общую концептуальную методологию создания VR-учебных материалов.

Стоит обратить внимание на тот факт, что на рынке отсутствуют гибкие 2D/3D VR/AR-конструкторы для разных целевых групп (средняя/высшая школа, полный или частичный интерактив, гуманитарные или технические специальности и др.). Кроме того, в настоящий момент все подобные программные продукты направлены на определённый пользовательский сегмент (для создания социальных приложений или компьютерных игр), в связи с чем пока отсутствует прямое продвижение в сфере музейных и исторических услуг, и данная маркетинговая ниша также не занята. Еще одной не менее важной причиной для разработки модуля-конструктора является отсутствие российских разработок в этой сфере.

На основании проведённого анализа возможных направлений нами выявлены следующие сферы, где может применяться предлагаемый VR/AR-конструктор:

- геймификация археологических исследований, раскопок (Lin et al. 2019, 229–238) и исторического наследия (Varinlioglu, Halici 2019);
- представление отдельных археологических находок, культурного и исторического наследия в виртуальной или дополненной реальности (Grevtsova, Sibina 2018, 90–102);
- создание образовательных курсов с элементами VR/AR на системах дистанционного обучения, например Moodle, для популяризации сохранения историко-культурного наследия, обучения студентов профильных специальностей, дополнительного образования и просвещения широких масс населения (Ellenberger 2017, 305–309; Garstki, Larkee, LaDisa 2019, 45–49);
- воссоздание с помощью конструктора VR/AR шаблонов различных виртуальных музеев, событий, производственных технологий, исторических публичных или иных мест (Schofield et al. 2018, 805–815), археологических памятников и пр. (Manju et al. 2020, 627–632).

Исходя из большого круга перечисленных выше исторических и археологических задач, где как предполагается использование создаваемой системы управления VR/AR-контентом, и потребностей конечных пользователей, которые не являются профессионалами в сфере информационных технологий, были выделены следующие критические требования к разрабатываемому программному обеспечению:

- система должна информировать пользователя о некорректном вводе информации;
- все сообщения должны удовлетворять требованиям понятности и логичности;
- выбор доступных 3D-моделей и сцен должен быть реализован наглядно, каждая доступная модель или сцена должна быть представлена в виде миниатюры;
- доступные 3D-модели и сцены должны быть сгруппированы (например, по предметным областям);
- все доступные сценарии работы должны содержать подробное описание;
- должна быть доступна функция редактирования сценариев;
- программа должна иметь "дружественный" и понятный интерфейс для неподготовленного пользователя.

В большинстве случаев созданные курсы и виртуальные пространства будут иметь возможность просматриваться с помощью смартфонов и устройств, схожих с Google Cardboard, поэтому главным видом контроля должно быть отслеживание взгляда.

При реализации перечисленных выше технологий, вариантов использования разрабатываемых технологий у специалистов, работающих с культурным наследием, должны будут появиться дополнительные профессиональные инструменты, упрощающие их работу, позволяющие создавать интересные конечному потребителю информационные продукты и позиционировать свои организации как идущие в ногу со временем.

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ОБРАЗОВАТЕЛЬНЫЕ ВОЗМОЖНОСТИ ВИРТУАЛЬНОЙ АРХЕОЛОГИИ (ОПЫТ ПРАКТИЧЕСКОГО ИСПОЛЬЗОВАНИЯ)

Глобальные вызовы современного мира приводят к трансформации высшей школы, в том числе и в нашей стране. И если в предшествующие годы этот процесс был относительно плавным, то пандемия COVID-19 просто не оставила университетам выбора. В новых условиях только тотальный переход к дистанционным образовательным технологиям позволил сохранить учебный процесс.

Долгое время значительная масса профессорско-преподавательского состава достаточно скептически относилась к использованию электронных учебных курсов, отдавая предпочтение личной коммуникации со студентами. В условиях пандемии стало очевидно, что одних лекций, проводимых на платформах онлайн-конференций, недостаточно для эффективной работы с аудиторией. Нужен другой рабочий инструмент, позволяющий обеспечить необходимое фактическое наполнение дисциплины и наладить коммуникацию между преподавателем и студентами. И таким инструментом стали электронные курсы. В наполнении дистанционных образовательных ресурсов незаменимы возможности виртуальной археологии.

В Сибирском федеральном университете существует своя система электронного обучения под названием «еКурсы», разработанная на основе платформы (LMS) MOODLE. На этой платформе создан и успешно реализуется курс «Археология. Источниковедческий практикум».

Согласно образовательной программе по направлению «История» дисциплина «Археология» изучается во втором семестре. Первоначально курс был построен по классической схеме: основное внимание уделялось специфике истории древнего и средневекового населения Сибири в разные хронологические периоды. Упор делался на знакомстве студентов с разнообразием археологических культур и их спецификой.

В последние годы классическая схема построения курса доказала свою неэффективность. Студентам первого курса не удавалось усвоить необходимый материал, а результаты обучения не соответствовали заявленным в программе компетенциям.

Связано это с целым комплексом причин. Во-первых, при поступлении абитуриенты сдают только гуманитарные дисциплины, соответственно, им не хватает базовых знаний по целому блоку естественнонаучных предметов, таких как география, геология, биология, физика, химия. Часто у них нет даже элементарных представлений об окружающем мире. Во-вторых, у учащихся не сформированы навыки чтения «длинных текстов», им сложно выделить основные мысли, разделить текст на смысловые блоки, сопоставить сведения из разных источников. Таким образом, работа на семинарских занятиях сводится к автоматическому чтению найденной информации, без её понимания и аналитики. В-третьих, студентам младших курсов не хватает знаний и общегуманитарного профиля. Во время первого года обучения они ещё слабо знакомы с общенаучной терминологией, не успели познакомиться с основами философии, источниковедения и методологией научных исследований.

В этих условиях курс по археологии переделан с учетом когнитивных особенностей студентов. В результате проведённой работы были пересмотрены результаты обучения, иначе скомпоновано внутреннее содержание курса, сделан упор на практических занятиях, на платформе «еКурсы» разработан полноценный электронный курс «Археология. Источниковедческий практикум».

Основной акцент в переработанном курсе сделан на знакомстве студентов с терминологией, методами полевых и лабораторных исследований, приёмами описания разных видов археологических источников, современными технологиями визуализации и презентациями археологических материалов.

Особое место в работе со студентами занимает именно электронный курс. Этот инструмент позволил разработать систему разнообразных оценочных мероприятий, насытить образовательный процесс новым по форме контентом, сформировать удобный справочный инструментарий.

При разработке электронного курса наиболее сложной задачей стала организация самостоятельной работы студентов. Если во время аудиторной работы они на практике знакомились с разными видами археологических материалов, то дистанционное обучение не предполагало раньше такой возможности. Выходом из ситуации стало широкое применение в электронном учебном курсе трёхмерных моделей артефактов.

Для этого использовался банк цифровых моделей археологических предметов, сформированный коллективом лаборатории Digital Humanities Сибирского федерального университета (Черкашин, Пиков, Романюк 2016). Ранее уже неоднократно подчёркивалась важность оцифровки объектов культурного наследия для его сохранения и актуализации (Гук и др. 2017), тогда как в образовательной практике потенциал подобных материалов в России явно использован в недостаточной мере.

Модели объектов культурного наследия используются в разных разделах электронного курса в соответствии с учебными задачами. Применение различных техник визуализации в обучении позволяет обеспечить его интенсификацию, а также активизировать познавательную деятельность студентов (Вербицкий 1991). Более того, одним из основных принципов обучения является принцип наглядности. Именно это качество образовательных компонентов позволяет получать полноценные знания и развивать логическое мышление (Усольцев, Шамало 2016).

В первую очередь оцифрованные модели археологического материала привлекаются в качестве иллюстративного материала в разделе «Глоссарий». Словесного описания орудий труда, оружия и украшений часто бывает недостаточно. Трёхмерные модели артефактов позволяют разглядеть предмет со всех сторон и составить о нём максимально полное представление. Кроме того, это добавляет курсу интерактивности, а также позволяет показать эпохальные изменения форм и видов орудий. При необходимости и наличии нужного контента возможна демонстрация многообразия типов предметов, обусловленного культурными, хронологическими или социальными различиями.

Активно используются трёхмерные модели артефактов для самостоятельной работы студентов. Учащиеся получают ссылку на ту или иную коллекцию предметов и соответствующие задания практического характера. Среди них: описание предметов по заранее заданным параметрам, описание коллекции, поиск датировки и культурной принадлежности находок, их классификация. Как показывает практика, наибольшие сложности возникают при работе с моделями изделий из камня, что обусловлено спецификой подобных материалов. Проверочные задания демонстрируют, что студенты, работающие с виртуальными моделями предметов, могут успешно выполнять аналогичные задания при работе с реальными артефактами.

Проведённый опрос среди 50 учащихся показал высокую эффективность использования трёхмерных моделей. Студенты отмечают высокую наглядность используемых материалов, тогда как описания предметов или их рисунки вызывают большие сложности при работе с ними. Абсолютное большинство студентов выразили желание попробовать самостоятельно получить подобные изображения.

Вместе с тем содержание образовательной программы требует новых подходов к формированию виртуальных коллекций археологических предметов. Чаще всего для оцифровки выбирают наиболее яркие и известные находки (предметы искусства, торевтику), тогда как для задач учебного курса часто необходимы наиболее типичные и массовые материалы, включая отходы производства. Было выявлено неравномерное наполнение раздела «Глоссарий», что необходимо учитывать при отборе предметов для создания трёхмерных моделей. Стала очевидна необходимость большой работы для создания изображений разнотипных археологических объектов (погребений, жилищ, хозяйственных ям, теплотехнических сооружений, целых поселков или городищ).

Таким образом, цифровые модели археологических предметов имеют широкий спектр применения в электронных образовательных курсах. Они позволяют не только сделать курс более наглядным и информативным, но могут эффективно использоваться в самостоятельной работе обучающихся, позволяя на практике отрабатывать необходимые навыки. Вместе с тем всё очевиднее становится необходимость в формировании цифровых компетенций у студентов направлений подготовки «История», «Археология», «Музейное дело».

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BUILDING DIGILAB – TOWARDS A DATA-DRIVEN RESEARCH IN CULTURAL HERITAGE

Introduction

E-RIHS – The European Research Infrastructure on Heritage Science, aims at providing new knowledge on the research, conservation and restoration of works of art, heritage assets, monuments and sites. As such, the target of its scientific investigation (paintings, sculptures, manuscripts, frescoes, icons, archaeological artefacts, building facades, architectural remains or heritage buildings, coins or ancient musical instruments, just to name a few) are stored in the hundreds of museums, art galleries, private collections and various other institutions, scattered all over Europe.

DIGILAB has been envisioned to primarily fulfill two main roles: integrate data predominately generated by FIXLAB, MOLAB and ARCHLAB analyzing the assets described above, and provide a set of digital tools for interrogating, processing, analyzing and interpreting such data, adding new knowledge. Thus, DIGILAB is envisioned as a knowledge creation space, in addition to its functions of curation of scientific data and management of reference collections and libraries (e.g. spectral libraries of pigments). Complementarily, it should provide catalogue information on ARCHLAB, and once its archives are digitized, integrate it within DIGILAB.

One can note the complexity of the task – both platforms combine a wide range of measurement techniques, instruments and methods. A quick look at the recently published catalogue of services on the IPERION-HS website shows a complex mosaic of techniques, expertise and disciplines converging in the domain of Heritage Science.

ARCHLAB provides access to organized scientific information in largely unpublished datasets from archives of prestigious European museums, galleries and research institutions. It enables physical access to the combined knowledge in 14 repositories in Belgium, France, Germany, Italy, Netherlands, Romania, Spain, Sweden and the UK. Data, in physical or digital form, have been collected through years of activities devoted to research and conservation of European cultural and natural heritage. Besides access to scientific, analytical and technical data on cultural objects, crafts, monumental and archaeological sites of international importance and related samples, access is provided to collections such as reference samples, art materials and several types of archaeological collections.

FIXLAB extends over twelve countries and twenty-seven laboratories, covering five main techniques categories, such as biology, mass spectroscopy or molecular analyses and combining expertise in a variety of disciplines. Access is offered to help address major questions raised by the materiality of Heritage Science artefacts in terms of their genesis, manufacturing processes, alterations, conservation and preservation. The unique services offered embrace advanced state-of-the-art instrumentation; dedicated facilities with teams of experts in the field of micro-analysis of HS artefacts; novel developments resulting from IPERION HS joint research activities to improve access progressively; development of both new sample-positioning devices at a micro-scale and software tools for the integration of imaging data. MOLAB is a world-class distributed infrastructure including key laboratories across ten European countries providing access to a set of mobile equipment and related competencies, for in-situ non-destructive measurements of artworks, collections, monuments and sites. The analysis may be orientated towards art-historical or archaeological questions (execution techniques, dating, under-drawings in paintings etc.; assessing the state of conservation of artefacts; determine or test the optimal preservation strategy to slow down alteration processes; monitoring conservation treatments and informing a risk assessment. All the techniques are non-invasive, so there is strictly no sampling or contact with the surface under exam.

Given the above picture, the task of generalizing workflows, processes and structures in order to integrate them within a comprehensive environment is difficult. The starting point is therefore a generic description of a typical workflow in Heritage Science. Figure 1 exemplifies such a characteristic workflow, aiming to be as generic and inclusive as possible. The left side of the mind-map details the stages of the workflow itself, while the right one details a specific example of analysis, tools and methods involved.

Any work starts from a well-articulated question on the reason why a measurement (or campaign of many measurements) is taken. This can be from the art history domain (e.g. which color mixtures were used by El Greco during his stay in Venice), conservation sciences (e.g. how one can identify the location, size, and stability of micro-fissures in the Michelangelo's David sculpture), restoration analyses (e.g. which materials can be used for the restoration of Medici letters written on Florentine papers?). Based on the above, researchers have to choose the most appropriate methods of analysis and tools, considering ethical aspects as well (e.g. invasive / non-invasive methods).

Consequently, researchers should follow protocols (if they exist or are required). These should guide them along the entire cycle of knowledge creation, from data acquisition, processing, post-processing, interrogation and interpretation of results. For example, protocols can detail how data should be captured (e.g. if sampling occurs, how a sample is extracted and treated), which software to use in order to process data and so forth.

Once the work objectives are clear and the investigation methods are chosen, instruments have to be set, their environmental conditions captured, data strategy defined and the optimal methods for data capture set. The same regards data analysis and derivation of conclusions.

Ideally, the entire process is formally captured in a set of information on how data has been produced. This is grouped under the terms "metadata" and "paradata", both providing the necessary tools to assure other users of the same data on its quality and usefulness

A standard Heritage Science based analysis starts with a thorough investigation of the background information on the analyzed asset(s). In the example presented in fig. 1, the asset is a painting; thus typical information that could be captured in a semantic metadata structure includes the object's history of ownership, a clear record of conservation interventions and related restorations, a description of the object from an art historical perspective and relevant curatorial data. These are often essential in making a first assessment of the reasons for the current conditions of the object and will dictate future interventions and measurements. Consequently, a common course of analysis proceeds from the macro to the micro, starting with a thorough investigation of the current state of the object's conservation, which may influence any subsequent step, and may affect different types of analyses in unique ways. Fig. 2 exemplifies the above mentioned steps, where the investigation workflow is linked with the why, what and how questions of the analysis, further detailed in fig. 3.

Fig. 1
A typical workflow in Heritage Science

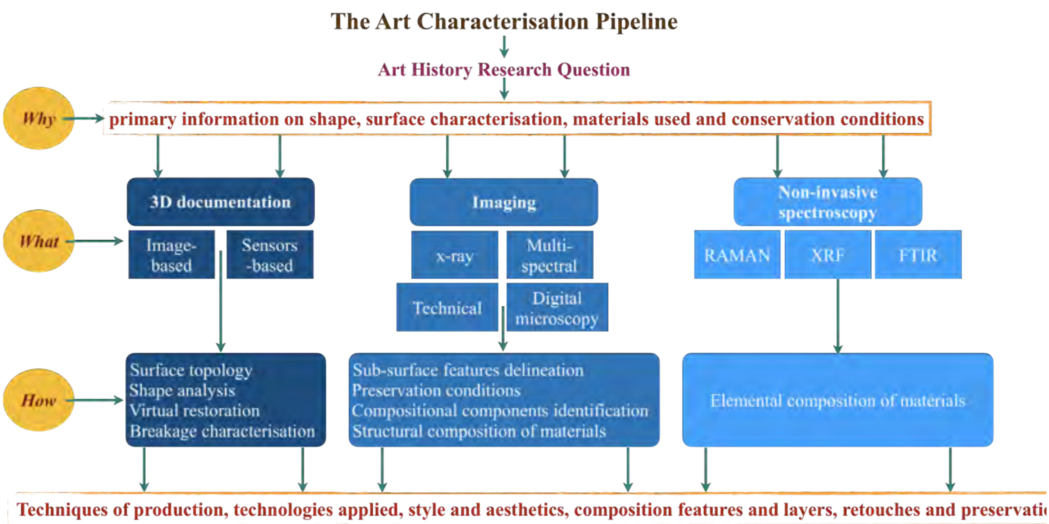

Fig. 2
An example of a painting analysis (The Cyprus Institute art characterization pipeline)

In this case, the first step is to characterize the overall shape of the analyzed artefact and its surface conditions (cracks, fissures, alterations in the overall geometry, etc.), followed by the materials used and conservation conditions. More detailed analyses follow, focusing on specific questions. Results indicate production methods, techniques and technologies applied, materials used and preservation conditions.

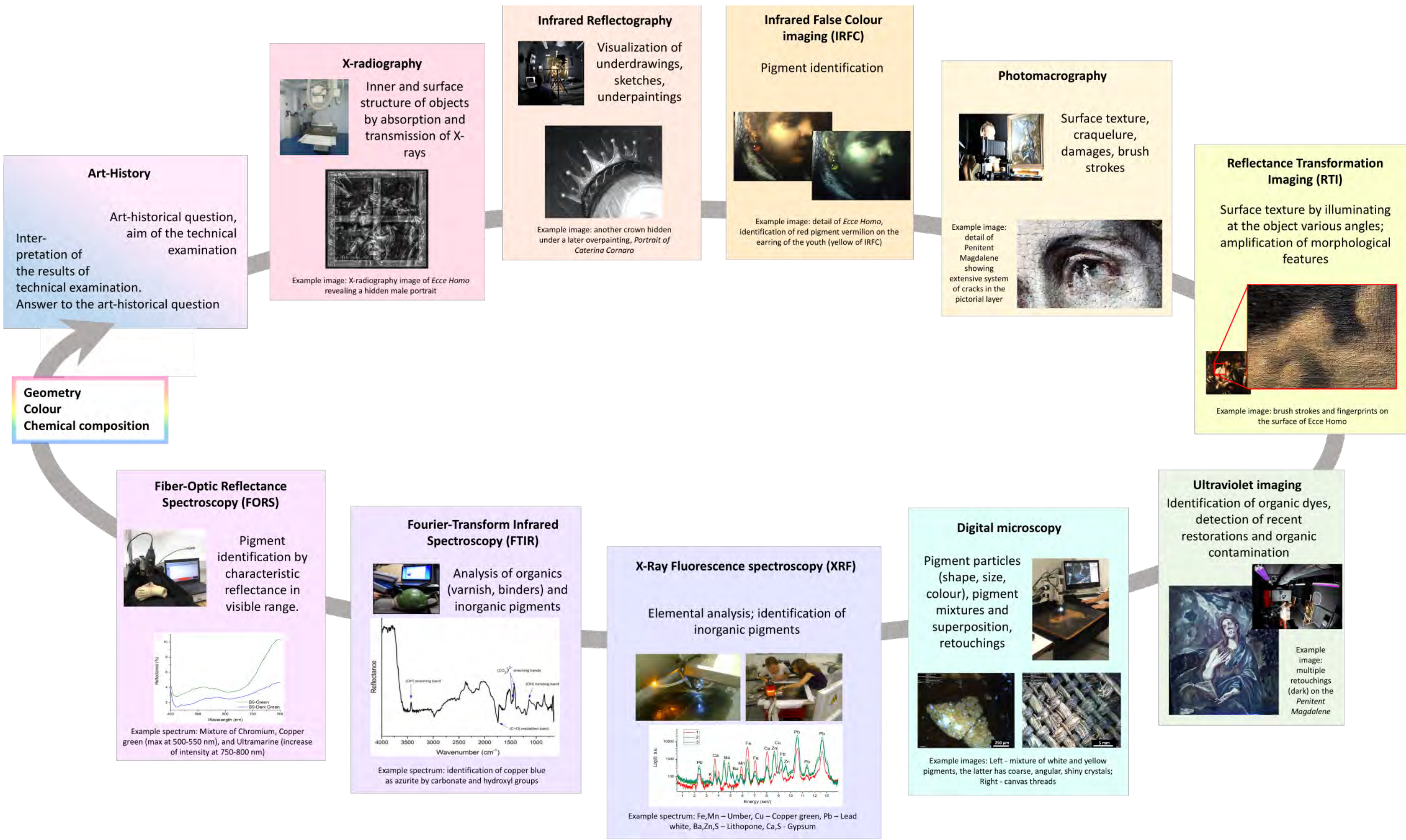

Fig. 3

A typical Heritage Science investigation pipeline (developed at The APAC laboratories, The Cyprus Institute)

Figure 3 describes the same pipeline with examples from non-invasive analyses on paintings, a recurrent request from many owners of works of art in the public or private sector. In the case described, x-ray radiography was performed in a hospital laboratory, which highlights the need for proper ethical and IPR metadata documentation. A series of imaging methods characterize the surface of the painting, followed by more specific methods of investigation. It is important to note the cyclic nature of analysis: the analytical results need to be corroborated with the art historical research, and this need represents one of the challenges to be captured within DIGILAB, in particular through its virtual research environment and collaborative tools (see below).

DIGILAB is described here at a conceptual level, with a Minimal Viable (MV) Structure detailed below. It consists of two main blocks – the data repository (DR) (with a federated / distributed structure) and a virtual research environment (VRE). Additional units consist of a separate section digitally hosting reference collections (e.g. lists of XRF-based pigments analyses of 16th century Italian paintings), and a catalogue of digital services offered by the VRE. A further component of DIGILAB regards the FAIR-isation of data and enrichment of its quality. DIGILAB should be able to primarily communicate with EOSC, the European Open Science Cloud, converging its content with it. DIGILAB is perceived as an aggregator of data from various content providers / repositories, thus it can be referred to as a federated repository. There are a variety of actors being able to ingest data, from individual researchers, to a laboratory, institution, at national level or at E-RIHS platform level (fig. 4).

The primary components of the DR are a data storage module, related to cleaning, storing and curating it, a semantic harmonization integration and inter-operability unit, enabling semantic mapping and overcoming language barriers and an ingestion and data retrieval unit, with related query / browsing tools. The VRE's main components are a virtual meeting room, conceived as a space where researchers from various disciplines can meet and discuss and enrich the data (e.g. through annotations) in front of a dashboard with a variety of collaborative tools offered. The VRE also contains data science tools for further data exploration and domain-specific tools, as detailed below in fig. 5.

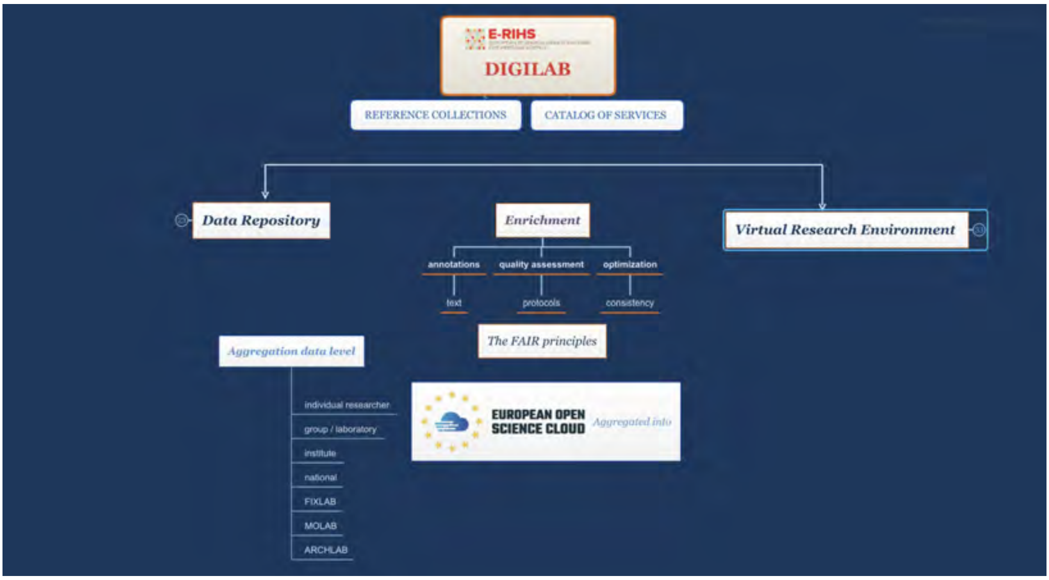

Fig. 4
Schematic structure of DIGILAB

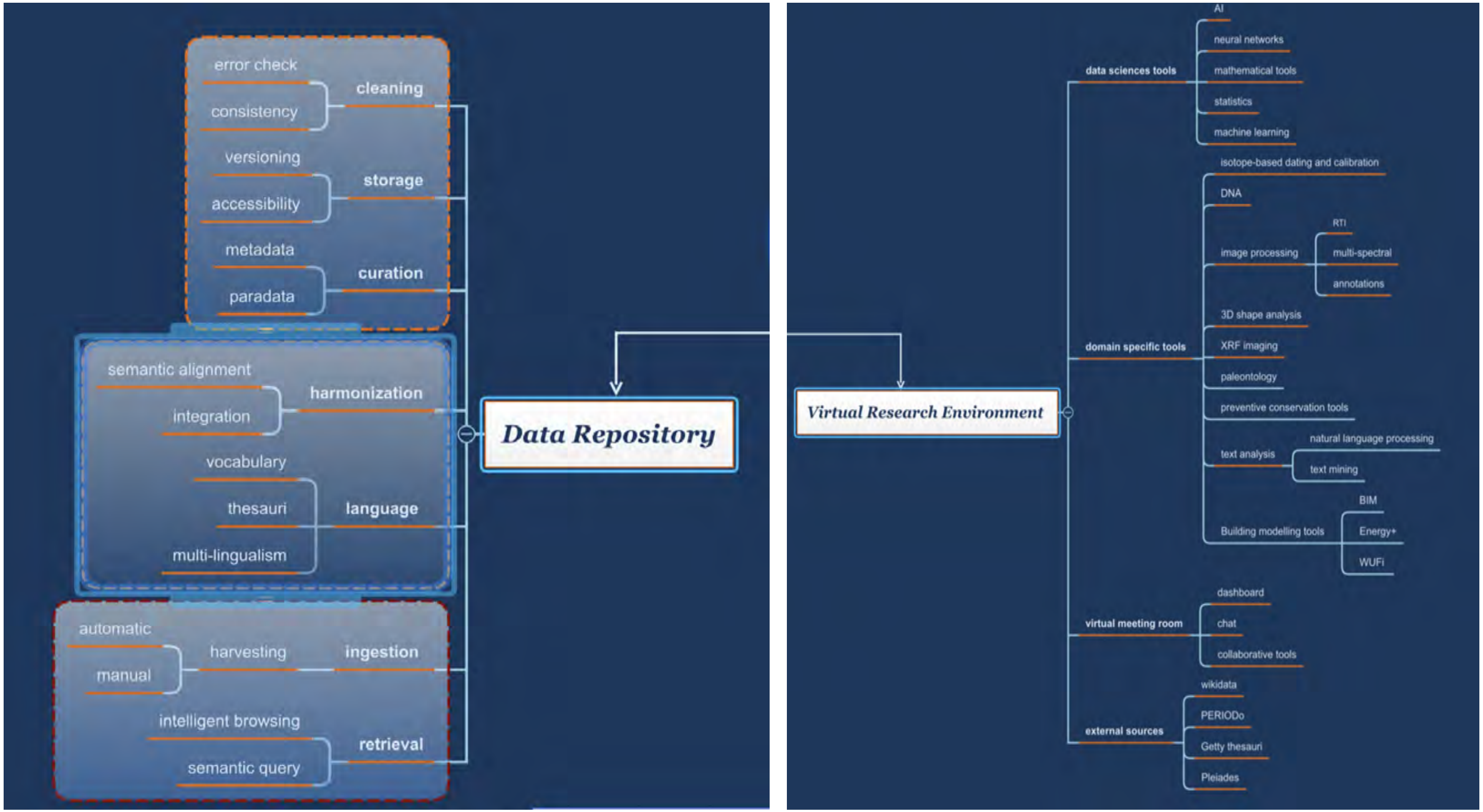

Fig. 5
Details of the MVS components of the Data Repository and the Virtual Research Environment

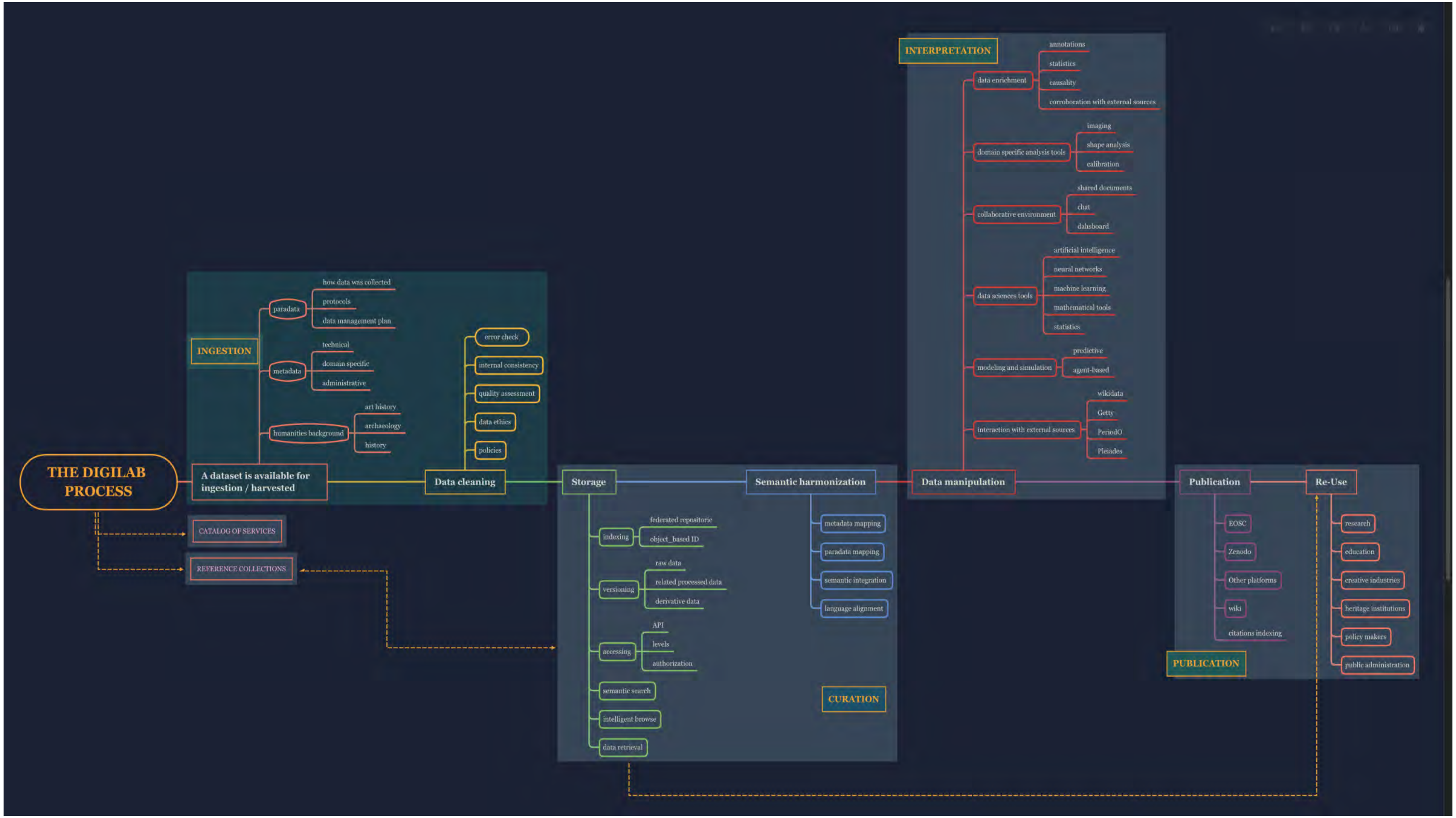

Fig. 6
The DIGILAB process

The DIGILAB process is described in fig. 6. There are four data processing stages: ingestion, curation, interpretation and publication / re-use. Reference collections and the catalogue of services are treated separately. Each component is described in more details below.

INGESTION (part of the data repository component of DIGILAB) (fig. 7)

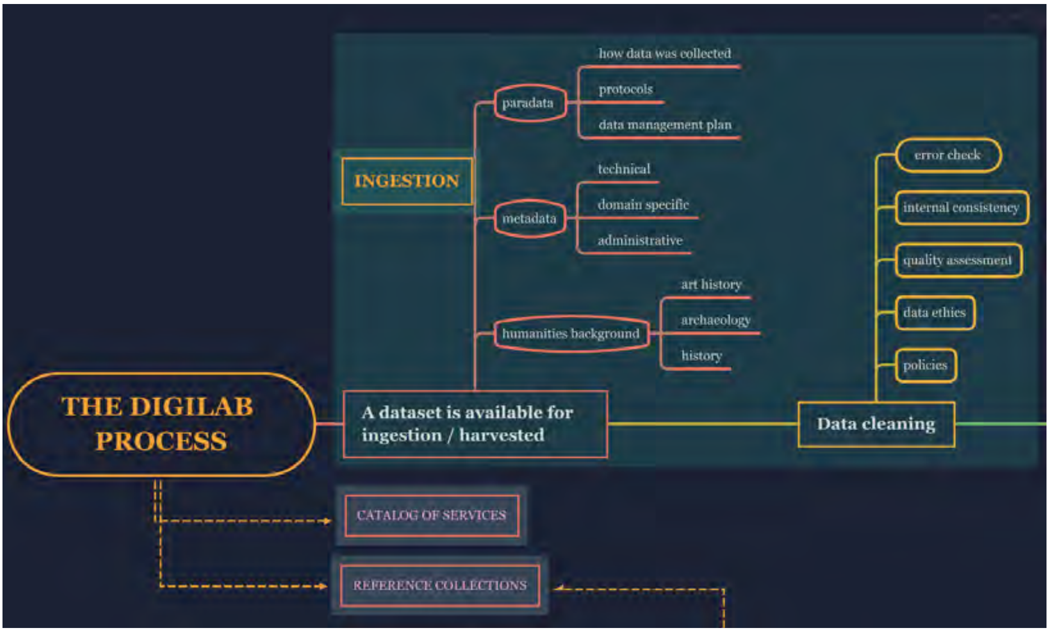

Fig. 7
The ingestion component of DIGILAB

Ingestion consists of two groups of actions: data/metadata ingestion and data cleaning. Data ingestion can be automatic (periodic check for data harvesting from other repositories) and manual, (directly by individual researchers or curators of data).

A. The primary information on data is grouped in three main categories:

- a. Humanities background
  - I. art history (including conservation/restoration descriptions)
  - II. archaeology
  - III. curatorial data
- b. Metadata:
  - I. technical information, possibly machine-generated
  - II. administrative data, e.g. ownership, IPR status, legal aspects
  - III. domain-specific – e.g. sample extraction method
- c. Paradata, i.e. information related to data provenance:
  - I. type of data (raw, processed, post-processed)
  - II. data generation steps (including e.g. calibration methods and data)
  - III. protocols applied when generating the data
  - IV. information on existing institutional data management plan

B. Data cleaning consists of the following steps:

- a. Identification of possible errors in data, e.g. missing fields, wrong dates

b. Consistency check, investigation of the data integrity
c. Data quality assessment, checking pre-defined parameters, automatically or manually
d. Data ethics clearance – IPR protection, compliance with ethical aspects, etc.
e. Policies – legal, operational framework applied when generating the data.

CURATION (part of the data repository component of DIGILAB) (fig. 8)

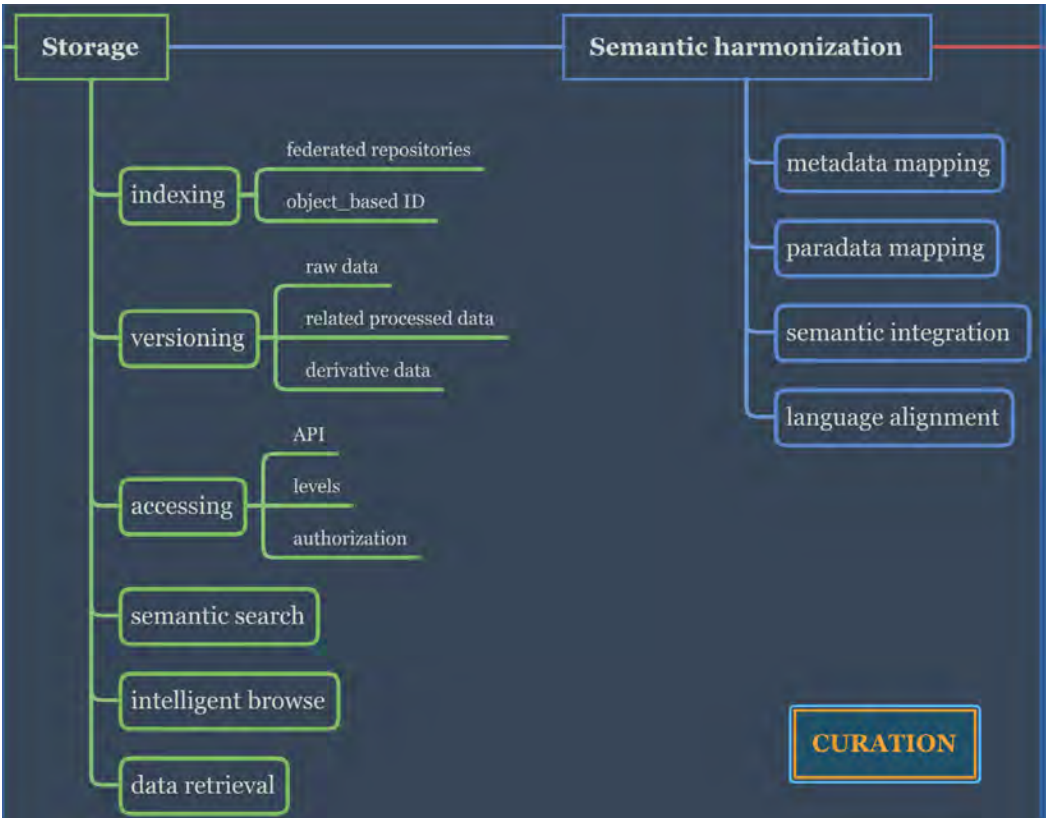

Fig. 8
The Curation component of DIGILAB

The curation stage has two main components:
A. Actions necessary for data storage:
a. Indexing, according to a federated repositories model, based on a persistent unique identifier of the analyzed object, for example
b. Versioning, considering aspects of type of data and its derivative ones, relation between a set of raw data and its processed and post-processed outcomes
c. Accessing, including authorization levels, API (application programming interface), definition of levels of access and modification rights on data, considering related data IPR
d. Semantic search and intelligent browsing options (e.g. through timeline, map-based, etc.)
e. Data retrieval options, considering IPR aspects and types of users.

B. Semantic harmonization, necessary to obtain data interoperability, including:
   a. Semantic metadata/paradata integration
   b. Language alignment

INTERPRETATION (the virtual research environment component of DIGILAB) (fig. 9)

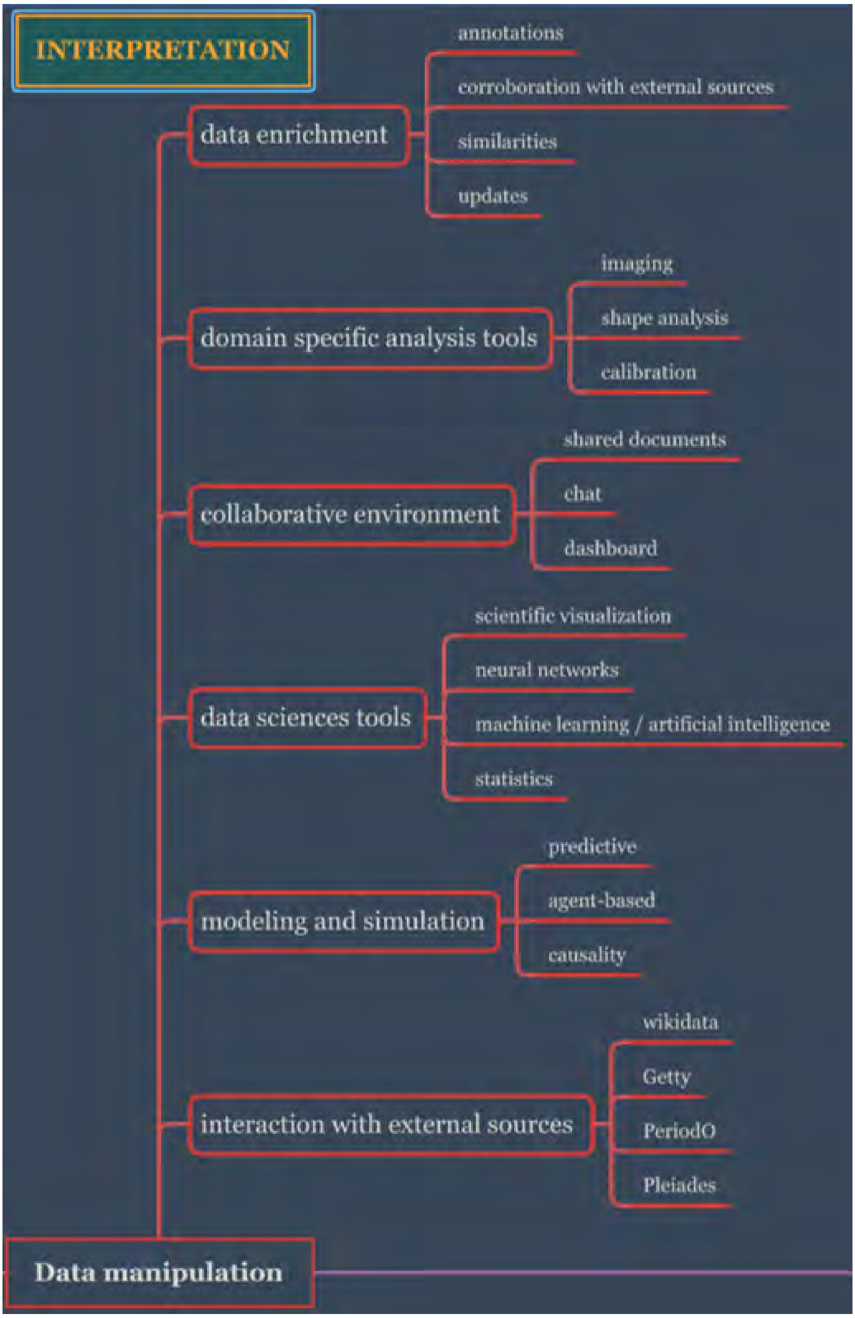

Fig. 9
The Interpretation component of DIGILAB

The main data reasoning block of DIGILAB, and consists of several main components:

A. A virtual meeting room, conceived as a collaborative environment, with:
- a. a dashboard with tools for interaction with data
- b. a multi-disciplinary dialogue through collaborative tools
- c. chat rooms as meeting points between humanities experts and those who performed the measurement and derivative analyses.

B. A data enrichment environment, linked with the dashboard, for:
- a. annotations as part of the interpretative process of data,
- b. interaction with similar external sources or
- c. update of information related to the investigated data.

C. A set of data sciences digital services – this is where various operations help researchers gain new insights into the data. These can be:
- a. machine learning tools, such as AI, ML etc.
- b. neural networks
- c. scientific data visualization tools
- d. mathematical tools

D. A complementary set of tools for performing primarily:
- a. Predictive (e.g. agent-based) modelling (e.g. location of production centers for glazed medieval pottery, given goods distribution models).
- b. Large-scale simulations of events (e.g. degradation of a building façade given specific environmental conditions within 5 years)
- c. Identification of patterns and characterization of causality between factors (e.g. demonstration that the use of oil lamps in churches decorated with frescoes causes degradation of certain colors).

E. Domain specific tools, such as:
- a. 3D – surface characterization (rugosity, roughness), 3D shape analysis, rendering and light simulation, etc.
- b. Imaging – RTI, image processing tools, multi-spectral imaging
- c. Tools for isotope-based data calibration, geo-chronology
- d. XRF quantification of data

F. Links with specialized external links that may help increase data quality and alignment in large-scale initiatives, such as:
- a. Thesauri (e.g. Getty)
- b. PeriodO (a gazeteer on period names – https://perio.do/en/)
- c. Pleiades (a gazeteer of ancient place names – https://perio.do/en/)
- d. Wikidata (knowledge graph – https://www.wikidata.org/wiki/)

PUBLICATION (the data repository component of DIGILAB) (fig. 10)

The publication component is the main link of DIGILAB with external users / platforms. It consists of two main categories, according to the nature and purpose of the link:

A. Publication in external sources, such as:
- a. EOSC – the European Open Science Cloud
- b. Zenodo and similar initiatives
- c. Citations indexing
- d. Wiki and related sources

B. Data re-use, by a variety of stakeholders, and according to IPR data clearance and profiling of users:

a. Research
b. Education
c. Creative industries
d. Heritage institutions
e. Policy makers and public administration
f. Industry

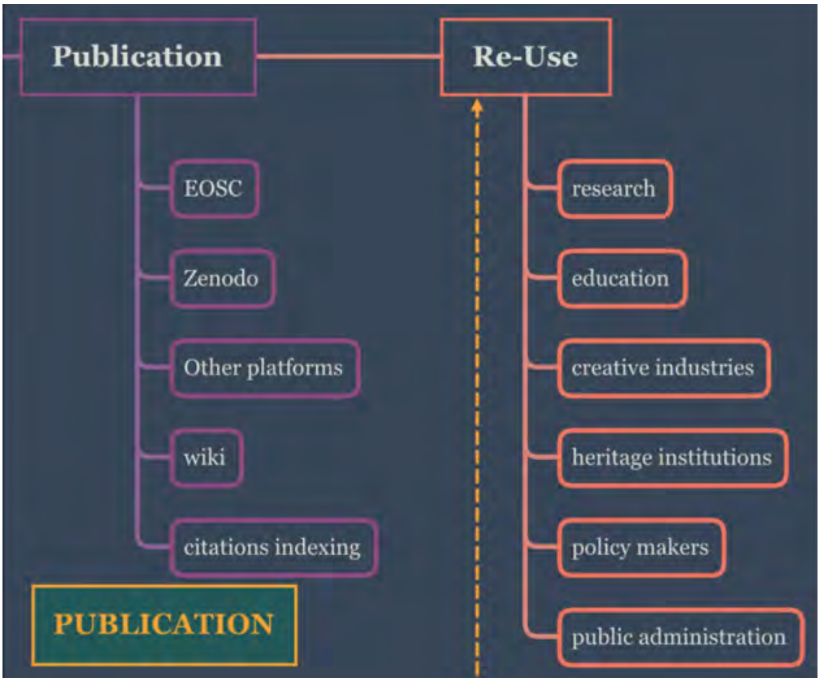

Fig. 10
The Publication component of DIGILAB

Requirements for DIGILAB implementation

DIGILAB starts from scratch. It is an ambitious project which requires profound transformations in the way researchers will conduct their future work. The concept of FAIR data, existing in many fields for several years now, is still in infancy in terms of implementation within the Heritage Science community. Adopting DIGILAB will require also institutions to design data management plans and implement them. The domain of Heritage Science is still fragmented, with researchers and labs working in isolation, data sharing being a utopian concept. Consequently, data provenance, while acknowledged as being important, is not yet implemented. Moreover, while researchers are used to look upon others' processed and interpreted data, they hardly share raw, primary data.

Therefore, it is recommended to focus future work on several levels:

A. Technical level:

a. Develop an authentication and authorization interoperability framework.
b. Definition of a persistent identifier framework, ideally to be linked with the Heritage asset persistent unique identifier (the ID of the Heritage asset). Consequently, a DOI assigned to a dataset, should be evaluated as well.

c. A data-access framework, where data is perceived as a service, in particular for the R (re-use) component of the FAIR principles.
d. A dataset discovery system based on metadata and content.
e. A service management and access framework, considering ethics and IPR.
f. A Service-Oriented Architecture (SOA) for data ingestion and documentation supported by Natural Language Processing (NLP).
g. Metrics for measuring quality (i.e. connectivity) of the semantic repository, and thus its ability to answer relevant questions (for the HS community).
h. Methodology, methods and techniques for supporting the evolution over time of the semantic repository and its relevance to the HS community.
i. A Support service: Helpdesk, FAQ, QA (based on Conversational Search).

B. Domain specific requirements:
a. Definition of a Heritage Science data model (building on existing initiatives within the CIDOC-CRM community, such as the CRMsci, CRMcr, CRMdig and relatable to the PARTHENOS data model).
b. An inter-disciplinary metadata framework, including descriptive information on the heritage asset analyzed, description on the projectable framework (according to the presented Heritage Science workflow).
c. Criteria for assessing data quality
d. Definition of internationally accepted protocols.

D. Sustainability requirements:
a. Setting of an open metrics framework for rewards and recognition
b. Costing access to DIGILAB services
c. Costing for the re-use of DIGILAB data
d. Agreed upon policies at national level
e. Implementation of data management plans.

IPERION HS aims at addressing some of the challenges presented above, in particular those related to levels II and III as described above. Looking at on-going similar initiatives, the interoperability framework and related knowledge repository proposed by the AriadnePlus project is among the most promising ones and DIGILAB should build on this accumulated expertise and related platform. Addressing level I from above, as well as developing the technical infrastructure of DIGILAB by its components and bringing it into an operational phase requires further substantial resources for research, development and implementation.

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VIRTUAL ARCHAEOLOGY: 10 YEARS IN VIRTUAL SPACE

Introduction

According to the system development life cycle framework (ISO/IEC/IEEE 15288), any technical project usually passes six stages: requirement analysis, design, development and testing, implementation, documentation, and evaluation. The international "Virtual archaeology" project is no exception. It was born thanks to the ideas of the ISAP London meeting in 2011 and contacts with the newly established Ludwig Bolzmann Institute for Archaeological Prospection and Virtual Archaeology. The concept of virtual archaeology was first proposed by Paul Reilly in 1990 who introduced the use of 3D computer models based on virtual reality for the visualisation of archaeological data (Reilly 1990). Since then, virtual archaeology has developed into a broad field of research and applications using the internationally recognised principles for the use of computer-based visualisation (London Charter Initiative 2009), while still missing its fundamental definition. That was the problem to discuss by the specialists interested in the topic. The sequence of all the activities based on the previous results has got the title International "Virtual archaeology" project with periodical conferences taking place.

Principles and methods

The First International Conference on Virtual Archaeology was organized by the Department of Eastern Europe and Siberian Archaeology and took place at the State Hermitage Museum from 4–6 June 2012 (fig. 1). The development of the conference website was supported by the Russian Foundation for Humanities (project No. 12-03-14006). Participants from 16 countries (Austria, Australia, Bosnia-Herzegovina, Cyprus, France, Germany, Italy, Japan, Netherlands, Romania, Russian Federation, Spain, Sweden, UK, Ukraine, USA) discussed the problems of using modern computer technologies for archaeological prospecting, data processing, modeling, archaeological reconstructions and visualizations. The conference program includes oral presentations, posters with demonstrations, and workshops on the technologies for multi-dimensional modeling of historical landscapes, archaeological monuments, objects and artifacts, GIS modeling of natural and historical processes, monitoring of cultural heritage and virtual reality design. The extremely well organised event (with an unforgettable social program) provided simultaneous translations from Russian and English, which not only made it easier for all the participants to follow the presentations but also facilitated lively debate amongst them. This provided very welcome opportunities to exchange ideas amongst all participants, breaking down perceived language barriers. Thus the meeting resulted in the official definition for Wikipedia in English (Virtual archaeology 2014) and in Russian (Виртуальная археология 2014).

Development of the project

Various non-commercial organisations (ADIT, ICOM, ICOMOS, LBI, LMU, ISAP) has been supporting the development of the website in order to provide a platform

Fig. 1
Participants of the first conference "Virtual archaeology – 2012"
near the New Hermitage in Saint Petersburg (photo by D. Hookk)

Fig. 2
Participants of the second conference "Virtual archaeology – 2015"
near the New Hermitage in Saint Petersburg (photo by A. Terebenin)

for the communication and demonstration of the best cases and achievements in virtual archaeology since 1st December 2013. These activities resulted in the Second International Conference taking place in 2015 again at the State Hermitage Museum (fig. 2). More than 80 participants arrived from 16 countries (Austria, Bulgaria, Estonia Germany, Greece, Spain, Italy, Canada, Cyprus, Poland, Romania, Russian Federation, Sweden, Ukraine, United Kingdom, United States of America) and 14 towns of Russia. The Vladimir Potanin Foundation provided the trip expenses for the leading specialists in frame of the "Museum Landing" programme. The programme included 38 presentations and 3 workshops. Each exiting report demonstrated new aspects of the virtual archaeology. Stratified archaeological deposits are complex data volumes perfectly suited for virtual approaches of investigation once the data from various sources are collected, including archaeological prospection results of whole landscapes or augmented reality environment derived from terrestrial laser recording. The number of participants has doubled up, online translation allowed the organizers to increase the auditorium by a third, and it became younger. Students and postgraduates discussed the problems on a par with leading professionals. Volunteers from the State Hermitage Museum coming from Belgium, Canada, Japan, Russian Federation, the United Kingdom, the United States of America played a great role in organisation (content management, translation, logistics).

The stable format and traditions of the conference were fixed: free participation and open access to the materials. The location in Saint Petersburg (Russian Federation) during the period of White Nights promoted informal meetings of colleagues and friends. The absence of the parallel sections, only oral presentations with simultaneous translation create comfortable environment for fruitful discussions. The main scope of the "Virtual archaeology – 2015" consisting of estimation and recommendations of the international experts in the field of digital cultural heritage for the future development of design methods and support of the projects in the field of virtual archaeology and virtual museums, as well as practical experience and technological exchange of specialists with professionals from museums, universities and scientific institutions can be considered completed.

Implementation of facilities

In 2018 we planned to discuss the achievements of virtual archaeology in the works from air, on the ground and underwater. However, the submitted reports have shown the fourth "fiery" element – museum. Thus, it is only natural that the necessary balance for the contacts of technical specialists and humanitarians was obtained in one of the most powerful museums of the world.

The next important aspect of the project became cooperation. While the scientific groups including archaeologists, museum specialists and designers from scientific institutions are a casual thing, the international teams working virtually is an achievement of the project. We always attract attention to the distribution of the points on the map, marking places where the participants come from. This time we are pleased to note the more equitable distribution on the territory of Russian Federation. The scientific contacts in Europe are easier due to the high concentration of universities and research centres. The big distances and territories in Russia make researches isolated and impede live communication. It is the aim to organise the creative interaction between leading scientific centres that was highly estimated by experts of the President Grant Foundation, supporting the International forum "Virtual archaeology – 2018" (fig. 3).

Perhaps a new step of cooperation should be a scientific network. An attempt was realized by SEAV with the objective "to integrate all university research groups, research centers, institutions, companies and professionals, who want to join a community of excellence,

Fig. 2
Participants of the third conference "Virtual archaeology – 2018"
at the General Staff Building in Saint Petersburg (photo by E. Sidorova)

that ratifies and pursues the precepts of the International Principles of Virtual Archaeology" (INNOVA 2016). An attempt to distribute knowledge through paid online courses without practice has failed. Any network must be permanent, actual and functioning. If one finds web pages without content or relevant information web analytics instruments record a bounce rate. The virtual archaeology works with information technologies, which must be relevant and up-to-date. Scientists in computer technologies believe the forecasts given by Gartner company based on the Hype cycle (Fenn, Raskino 2008). Taking in account this methodology we could say that hype was passed around 2015 and COVID-19 pandemics dragged everyone into "the trough of disillusionment". "The slope of enlightenment" led to the on/off-line conference "Virtual archaeology – 2021" at the Siberian Federal University.

Documenting virtual archaeology

The development of virtual archaeology has been documented from different view points since its appearance to the present day (Ryan 2001; Beale, Reilly 2014; Niccolucci, Hermon, Doerr 2015; Hookk 2016; Cultural Heritage: Digitization 2018; Forte 2019). The International "Virtual archaeology" project supports its own website (www.virtualarchaeology.ru), public pages in social media (Twitter, Facebook, Instagram) with its hashtags (#va2012, #va2015, #va2018, #va2021) and has published the hard copy of the proceedings (Virtual archaeology 2013; Virtual archaeology 2015; Virtual archaeology 2018) under support of the State Hermitage Museum, where impressive results are presented by the authors of the most picturesque presentations. The theoretical aspects are described along with practical conclusions in the same context. These publications are in open access on the project website and provide a valuable handbook for anybody who is interested in virtual archaeology.

System approach to the evidence or "plateau of productivity"

There are no universal methods for performing system analysis. It is generally considered that it is essential to determine the laws of system functioning, the formation of alternative algorithms and the choice of the most appropriate solution to the problem. Sometimes the main task is just to state the problem. Since the first meeting in Saint Petersburg, the "Virtual archaeology" project has joined together enthusiasts mainly from European countries and has resulted in powerful impulse of integration of the non-destructive methods in the investigation of the domestic archaeological monuments. It revealed young specialists working in regions where the active archaeological research include the impact of virtual archaeology methods. Every conference had a certain scope. Every time the programme committee applied the methods of brainstorming and the choice of collective solutions.

Thanks to virtual worlds, there is a great potential for actions aimed at gaining knowledge and learning. This is where scaling, transduction, and materialization are possible. In the virtual world, you can change your spatial characteristics relative to the object being studied for a more detailed investigation. Such examples already exist with 3D scanning or micro-CT for restoration processes, anthropology, and biology (Virtual archaeology 2018, 58–64, 104–105). Transduction of the signals from LIDAR, laser scanning magnetometer, gives researchers new information about invisible structures. Finally, complex data can be transformed into a digital 3D model suitable for materialization.

All of the above-mentioned knowledge acquisition opportunities are not available in the real world, but they represent a huge potential for research and education (Гук 2018). To confirm this, the scope of the "Virtual Archaeology – 2021" was formulated as follows: "Revealing the Past, Enriching the Present and Shaping the Future". The long-standing dream of spreading European technologies on the territory of Russia as far as the Pacific Ocean has finally come true. On the "plateau of productivity", virtual archaeology as a field of applied science requires practical training and implementation in real life. The proceedings published in the actual book depict the methods of virtual archaeology helping to get results in field studies, and are useful for the following dissemination of cultural heritage in the museum institutions and for educational activities.

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РЕЗЮМЕ / SUMMARIES

Пол Рейли, Иан Доусон

НА ПУТИ К ВИРТУАЛЬНОМУ ИСКУССТВУ/АРХЕОЛОГИИ

Количество изображений, «записывающих» археологический ландшафт и музейные коллекции в мельчайших деталях в планетарном масштабе, всё возрастает. Но на кого рассчитаны эти процессы сканирования, осуществляемые в промышленных объёмах? Ни один человек, или даже целая армия людей, не сможет просмотреть, не говоря уже о том, чтобы проанализировать и малую часть гигантских объёмов порождаемых каждый день и уже перенасытивших виртуальное пространство изображений. Вместо человека эти изображения будут анализировать машины. Что же они увидят? В нашей статье мы попытаемся ввести некоторые дифракционные и намеренно подрывные художественные/археологические перспективы, касающиеся представления археологических артефактов и коллекций, в частности, в отношении того, как передаётся окружающая обстановка и расположение мест их обнаружения. Для переосмысления представления артефактов и коллекций будет использована широкодоступная техника искусственного интеллекта «Перенос стиля» (Style Transfer).

Ключевые слова: искусство/археология, визуализация, машинный интеллект, перенос стиля.
Keywords: art/archaeology, imaging, machine intelligence, Style Transfer.

Перевод Е. Г. Гавриловой

Irina Ponkratova, Sergey Batarshev

RUSSIAN HORIZONS OF THE "TERRITORY": THE EXPERIENCE OF ORGANIZING A VIRTUAL EXHIBITION BASED ON THE RESULTS OF THE RESEARCH OF GIZHIGINSK'S ARCHAEOLOGICAL EXPEDITION

Virtual exhibition "Gizhiginsk's archaeological expedition: discoveries of 2019–2020" was created in November 2020 as part of the Third All-Russian Scientific and Practical Conference with international participation "Universities of Russia in a Dialogue with Time" and is timed to coincide with the 60th anniversary of the North-Eastern State University, Magadan. The purpose of the exhibition is a public demonstration of the results of the studies of the cultural heritage object "City of Gizhiginsk" in the Severo-Evensky District of the Magadan Oblast. The exhibition presents topographical instrumental plans of the object with the adjoining area based on the orthophotomap made according to the data of DJI Phantom 4 Pro UAV with the help of Photo Scan software system as well as photographs of household and trade items, weapons, religious paraphernalia, tableware, jewelry, toys, coins, etc. The exhibition was created with the help of MS Power Point presentation system, which allows to quickly present the results of the field season.

Keywords: North of the Russian Far East, Gizhiginsk's archaeological expedition, object of cultural heritage, town Gizhiginsk, residential landscape, ortophotography, UAVs.
Ключевые слова: Север Дальнего Востока России, Гижигинская археологическая экспедиция, объект культурного наследия, город Гижигинск, селитебный ландшафт, ортофотосъёмка, БПЛА.

Translated by E. Gavrilova

Николас Шимерль, Пиа Патриция Вебер, Томас Штёльнер

ПЕРЕОСМЫСЛЕНИЕ АНАЛОГА – ОТ ВИРТУАЛЬНОЙ АРХЕОЛОГИИ К ЦИФРОВОЙ ВЫСТАВКЕ

Солевые люди Зенджана – единственные солевые мумии, сохранившиеся до нашего времени, их возраст составляет около 2000 лет. Они были найдены в иранской соляной шахте. В результате этого открытия в соляной шахте и её окрестностях на протяжении более чем 15 лет проводились международные и междисциплинарные исследования. В последние годы археологические раскопки активно поддерживались цифровой документацией в полевых и офисных условиях. Например, были созданы 3D-модели, отображающие ход раскопок и находки, а также модель местности высокого разрешения, охватывающая площадь примерно 4,5 км^2. Затем эти выдающиеся результаты исследований преобразовали в специальную выставку, которую сейчас можно посетить из любой точки мира в режиме онлайн. Цифровая версия выставки является точной копией аналогичной выставки, представленной в музее, но имеет более высокий уровень детализации и содержит более 80 3D-моделей находок, связанных с солевыми людьми, а также дополнительную информацию и интервью с участниками исследований. В своём выступлении мы хотим представить наш результат, полученный в процессе создания цифровых данных, а также предложить новый способ распространения результатов археологических исследований среди широкой аудитории.

Ключевые слова: горная археология, фотограмметрия, 3D-моделирование, солевые мумии, выставки, виртуальный музей, научная коммуникация.
Keywords: mining archaeology, photogrammetry, 3D modelling, salt mummies, exhibitions, virtual museum, science communication.

Перевод Е. Г. Гавриловой

Боян Миятович, Сельма Ризвич

VR-ВИДЕО В ЦИФРОВЫХ ПРИЛОЖЕНИЯХ ДЛЯ ОБЪЕКТОВ КУЛЬТУРНОГО НАСЛЕДИЯ

Цифровые технологии являются превосходным инструментом для представления и сохранения культурного наследия. Цифровые приложения для объектов культурного наследия представляют собой комбинации 3D-моделирования, цифрового сторителлинга, визуальных искусств, компоновки, фотограмметрии, виртуальной и дополненной ре-

альности. Виртуальная реальность или видео 360 – это новый стандарт в кинематографе, когда зритель помещается в центр видео. Зритель больше не является пассивным наблюдателем. Он/она может поворачиваться и взаимодействовать с видео. VR-видео действительно погружает зрителя в снятую сцену. В этой статье мы представляем новые правила кинематографа и грамматику киноязыка VR-видео. Мы знакомим читателей с VR-камерами, основными правилами производства VR-видео, а также с сильными и слабыми сторонами VR-видео в рамках цифрового представления культурного наследия.

Ключевые слова: цифровое культурное наследие, VR-видео, видео 360, виртуальная реальность, интерактивный цифровой сторителлинг.
Keywords: digital cultural heritage, VR video, 360 video, Virtual Reality, interactive digital storytelling.

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ПРИМЕРЫ ИСПОЛЬЗОВАНИЯ ФОТОГРАММЕТРИИ

В данной статье рассматривается практическое применение фотограмметрии для документирования культурного наследия во всём его многообразии, поскольку этот метод применим в больших масштабах – от ландшафтов до небольших объектов. Здесь объясняются особые требования, предъявляемые к фотограмметрии в зависимости от масштаба, а также рассказывается о методах визуализации и необходимом оборудовании. На различных примерах из практики в Боснии и Герцеговине продемонстрирована и изучена специфика каждого случая, а также показано, что полученные результаты подходят для целого ряда известных аналитических методов и предлагают множество вариантов презентации. Это ещё и отличное представление о заманчивом методе документирования, который не требует больших финансовых затрат на дорогостоящее оборудование и является одинаково быстрым и надёжным.

Ключевые слова: фотограмметрия, примеры использования, культурное наследие, документация.
Keywords: photogrammetry, case studies, cultural heritage, documentation.

Перевод Е. Г. Гавриловой

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POSSIBILITIES OF THE RECONSTRUCTION OF A BROKEN CERAMIC VESSEL

One of the problems of archaeological research is the reliable restoration of the original appearance of an ancient ceramic pot from its fragments found during excavations. It is still difficult to solve this problem with the help of computer technologies, although certain steps have already been taken in this direction by foreign and domestic specialists. In reality, during the desk processing of finds, ceramic fragments are manually selected to match each other, sequentially glued, following which further reconstruction of their appearance is performed, as a rule, hypothetically, since it is often not possible to completely restore the pot. In this article, the authors attempt to use a mathematical model to reconstruct the geometric shape of a pot with missing essential pieces found in the Altai burial of the Pazyryk culture. At each stage, based on the implemented computer capabilities, the reliability was checked and, as a result, a complete visual "restoration" was performed. The article shows an algorithm for solving this problem, which can be used to work with other similar finds not only from the monuments of the Pazyryk culture, but also with various archaeological finds of antiquity, the Middle Ages and modern times. To obtain a 3D model of the pot, "Meshroom" software was used, as well as the U-Net neural network with pre-trained models. For the technical calculation during the computer "restoration" of the pot, MATLAB R2020b version application software was used. As a 3D visualization platform, Autodesk 3dsMax 2020 Athena with the V-Ray Next rendering system was used. In addition to describing the entire procedure and the results obtained, the article demonstrates a number of relevant illustrations. The work was partially supported by the Russian Foundation for Fundamental Research (Project № 20-39-90022).

Keywords: Pazyryk culture, Scythian-Saka time, photogrammetry, mathematical model, computer reconstruction.

Ключевые слова: пазырыкская культура, скифо-сакское время, фотограмметрия, математическая модель, компьютерная реконструкция.

Translated by E. Gavrilova

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THREE-DIMENSIONAL MODELS OF MEDIEVAL STONE CROSSES USED AS A MODEL FOR DISPLAYING ARTIFACTS FROM "INACCESSIBLE" PLACES

Medieval stone crosses widespread on the territory of the Novgorod Land in XII–XVI centuries are the monuments that are quite difficult to study. This is due, firstly, to the specifics of their location – few crosses have survived in rather remote villages or forests mostly in Leningrad, Novgorod and Pskov regions. In addition, since the end of the XIX century, stone crosses have been entering the collections of regional and central museums; most of them are not published. By the beginning of the XXI century, crosses that used to belong to one group (for example, coming from the village of Voynosolovo) could be divided – some of them being stored in situ, and some of them being a part of the collection at three or four different museums.

In 2019 the State Hermitage Museum expedition together with the Siberian Federal University started to publish 3D models of the crosses studied during fieldwork on the Hermitage Electronic Encyclopedia website. We also publish crosses which are stored as closed collections. This allows us not only to show qualitative images of artifacts which are difficult to access but also to reconstruct fragmented groups within virtual space.

Keywords: medieval stone crosses, archaeology of Novgorod Land, ancient Russian art, ethnography, museum collections.

Ключевые слова: средневековые каменные кресты, археология Новгородской земли, древнерусское искусство, этнография, музейные коллекции.

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СМЕНА ПОДХОДОВ: АРХЕОЛОГИЧЕСКАЯ ПРАКТИКА В ЭПОХУ ЦИФРОВЫХ ТЕХНОЛОГИЙ

Технологии визуализации оказали значительное влияние на восприятие исследователями археологической информации. Новые методы и средства визуализации дали учёным возможность испытать новые формы взаимодействия, сократить расстояние между физическим и цифровым пространством и укрепить идею Эджворта, что они имеют «эффект, выходящий далеко за пределы сфер открытия». Археологические данные реализуют различные смыслы в разных предметных областях, и для того чтобы использовать эти данные в качестве средства обоснования новых знаний, мы должны решить сложную задачу выхода за рамки традиционных методов. Виртуальное, реальное, цифровое и физическое больше не являются отдельными сферами. Благодаря активному взаимодействию с массивами данных, постоянно перемещающимися по различным измерениям, стало возможным испытать интерпретационные процессы, которые приводят к выделению новой информации.

В данной статье будут рассматриваться возможности, связанные с археологическими исследованиями, проводимыми в разных предметных областях.

Ключевые слова: археологическая практика, цифровая археология, визуализация в 3D.
Keywords: archaeological practice, digital archaeology, 3D visualization.

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АКТЁРСКАЯ ИГРА И РЕЖИССУРА В ЦИФРОВЫХ ПРИЛОЖЕНИЯХ ДЛЯ ОБЪЕКТОВ КУЛЬТУРНОГО НАСЛЕДИЯ

С момента возникновения первых театров актёрская игра и режиссура определялись набором правил, и это привело к эффективной передаче эмоций и сообщений зрителям. С развитием кинематографа некоторые из этих правил сохранились, а некоторые были адаптированы к новым медиа. В настоящее время технологии виртуальной реальности снова трансформируют актёрское исполнение и режиссуру, следуя новым концепциям и новым способам выражения и увеличивая погружение зрителя.

В этой статье мы представим опыт актёров и режиссёров, участвующих в создании цифровых приложений для объектов культурного наследия. Мы определим основные сильные стороны и ограничения виртуальной реальности, связанные с актёрской и режиссёрской работой, чтобы перенести наших зрителей в прошлое культурных памятников и дать им возможность почувствовать жизнь внутри них.

Ключевые слова: цифровое культурное наследие, актёрская игра в VR-видео, режиссура VR-видео, виртуальная реальность, интерактивный сторителлинг.
Keywords: digital cultural heritage, acting in VR video, directing VR video, virtual reality, interactive digital storytelling.

Перевод Е. Г. Гавриловой

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PROSPECTS OF USING VR/AR CONTENT MANAGEMENT TOOLS IN ARCHAEOLOGY

The Irkutsk National Research Technical University is developing a platform for content management based on virtual and augmented reality (VR/AR). The platform can be used for various tasks of the educational process as well as for presentation purposes, including those in archaeology. The platform being developed can be used in educational courses, for example, by integrating it into the Moodle and other learning management systems.

Virtual and augmented reality (VR/AR) is covering more and more areas of application. Researchers often implement VR/AR-related projects in archaeology. Archeology is included in the curriculum for history students and popular science programs are offered for children and adults. At present, virtual exhibitions of archaeological finds in museums and at various traveling exhibitions have also become widespread, with 3D models of archaeological materials obtained in different ways being accumulated in electronic form.

Keywords: virtual reality, augmented reality, archaeology, presentation of results.
Ключевые слова: виртуальная реальность, дополненная реальность, археология, представление результатов.

Translated by E. Gavrilova

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EDUCATIONAL OPTIONS OF VIRTUAL ARCHAEOLOGY (PRACTICAL USE EXPERIENCE)

Digitalization of higher education leads to an increase in using e-learning courses. The pandemic has shown that it is an effective working tool providing the necessary factual content of the discipline and establishing communication between the professor and students.

It was a result of updating the course in the discipline of archaeology for the students of the Siberian Federal University specializing in history that three-dimensional models of archaeological objects began to be widely used. 3D models are used as illustrative material ("Glossary" section of the course), and students' individual work is organized with their help as well. Students practice their skills of describing different categories of artifacts, their typology and determining cultural and chronological affiliation. Tests showed that students who worked with virtual models of objects can successfully apply in practice their knowledge from the theoretical part of the course.

At the same time, the content of the educational program requires new approaches to the formation of virtual collections of archeological objects. There is a separate issue of copyright with regard to the use of models in electronic courses of higher education institutions.

Keywords: archaeology, education, 3D modelling, e-learning courses.
Ключевые слова: археология, образование, трёхмерные модели, электронные курсы.

Translated by E. Gavrilova

Сорин Хермон

СОЗДАНИЕ DIGILAB – НА ПУТИ К ИССЛЕДОВАНИЯМ КУЛЬТУРНОГО НАСЛЕДИЯ НА ОСНОВЕ ДАННЫХ

DIGILAB состоит из исследовательских центров, занимающихся изучением наследия с помощью интегрированных цифровых данных в области науки о сохранении наследия, цифрового наследия и гуманитарных наук. Она предлагает онлайн-доступ к цифровым сервисам и исследовательским инструментам, экспертным знаниям и ресурсам. Она предоставляет доступ к исследовательским данным, изначально созданным в FIXLAB, MOLAB и ARCHLAB в рамках E-RIHS (Европейской научно-исследовательской базы науки о сохранении наследия), проверяя их на соответствие принципам FAIR data и обеспечивая их совместимость, а также к системе Virtual Research Environments, где исследователи могут получать доступ к таким данным, визуализировать их, производить запросы и управлять ими с целью создания новых знаний, связанных с наследием. DIGILAB стремится к согласованию с EOSC (Европейским открытым научным облаком).

Ключевые слова: исследование больших данных, научно-исследовательская база, принципы FAIR data, цифровое культурное наследие, наука о сохранении наследия.
Keywords: archaeology, big data research, research infrastructures, FAIR data principles, digital cultural heritage, heritage science.

Перевод Е. Г. Гавриловой

Дарья Гук

ВИРТУАЛЬНАЯ АРХЕОЛОГИЯ: 10 ЛЕТ В ВИРТУАЛЬНОМ ПРОСТРАНСТВЕ

Более 10 лет назад научное сообщество объединило свои усилия по внедрению в археологию неразрушающих методов и принципов виртуальных реконструкций. Международный проект, поддержанный некоммерческой организацией, а также Государственным Эрмитажем, позволил молодым специалистам установить контакт с профессионалами в области 3D-моделирования, геофизики, аэрофотосъёмки во всём мире.

Три года между встречами – это как раз подходящий срок для успешной реализации проекта, достойного быть представленным международному научному сообществу. Благодаря поддержке со стороны различных фондов и коммерческих организаций площадка была перенесена из музея в университет, что свидетельствует о важности знаний для нового поколения исследователей. Необходимо отметить значимый вклад проекта «Виртуальная археология» в развитие научного сотрудничества и распространение опыта от Европы до Дальнего Востока, от Запада до Востока, с оптимистичным движением в будущее даже в сложное время пандемии.

Ключевые слова: виртуальная археология, научное сообщество, международная конференция, международное сотрудничество.
Keywords: virtual archaeology, scientific society, international conference, scientific cooperation.

Перевод Е. Г. Гавриловой

СПИСОК СОКРАЩЕНИЙ / LIST OF ABBREVIATIONS

БПЛА	беспилотный летательный аппарат
ADIT	Automation Directions in Museums and Information Technologies
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
CCD	Charged Couple Device
CNN	Convolutional Neural Network
DOI	Digital Object Identifier
DR	Data Repository
E-RIHS	European Research Infrastructure on Heritage Science
EOSC	European Open Science Cloud
FAIR	Findable, Accessible, Interoperable, Reusable
FVV	free-viewpoint video
GIS	Geographic Information System
HD	high-definition
HMD	Head Mounted Display
HS	Heritage Science
ICOM	International Counsil of Museums
ICOMOS	International Counsil on Monuments and Sites
IEEE	Institute of Electrical and Electronic Engineers
IPR	Intellectual Property Rights
ISAP	International Society for Archaeological Prospection
LBI	Ludwig Bolzmann Institute
LIDAR	Light Detection and Ranging
LMU	Ludwig-Maximilians-Universität München
ML	Machine Learning
MV	minimum viable
NLP	Natural Language Processing
QR-code	Quick Response code
RTI	Reflectance Transformation Imaging
SOA	Service-Oriented Architecture
TLS	terrestrial laser scanning
UAV	Unmanned Aerial Vehicle
VE	Virtual Environments
VR	Virtual Reality
VRE	Virtual Research Environment

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