Defining a Methodology for 3D Approximations in Archaeology: The Issue with Alternative Models

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3D reconstruction (here referred to as 3D approximation) is widely used today in archaeology, yet its methodology has not entirely been accepted within traditional practices. Partially due to a lack of standards and theoretical support, partially due to mistrust for new technology, key issues in the handling of 3D data are yet to be resolved. This is especially true with the management of imprecision and subjectivity within 3D approximations. The use of metadata and paradata have minimised concerns, but there is yet to be clarity on the preferred method of displaying uncertainty. One solution proposed has been the creation of alternative models, displaying conflicting theories within the 3D approximations.

Here we discuss the advantages and flaws of this technique, ultimately demonstrating its limitations and proposing a more theoretical approach to the issue. Creating alternative models of conflicting hypotheses can be of great use in specific cases, especially when the interpretation of an archaeological site is unsure. But it is not a general solution to the problem of uncertainty. Limited publishing space and a need to propose a clear narrative to the public seriously hinder the use of alternative models. Additionally, technical limitations in the approximation process can lead to prolonged design times. As a response we propose the establishment of solid guidelines and the investigation of the theoretical background of 3D approximation to align this methodology with traditional practices. Demonstrating the similarities between new and old practices will minimise issues of uncertainty and help establish the validity of 3D approximations. The use of metadata and paradata is also advocated, in order to avoid black-box research and allow accountability and replicability.

This paper is part of a process of assessment and analysis of the 3D method, in an attempt to create a solid philosophical background that can withstand current criticism and ultimately result in a wider use of high quality 3D approximations in archaeology.

Key words:
3D reconstruction, 3D theory, alternative models, hyperreality, metadata, paradata, 3D approximations.

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INTRODUCTION

The use of Visualisation techniques is on the rise in archaeology. From photogrammetry to VR, every year new and exciting projects are published, showcasing innovative methodologies and spectacular results. The field is ever expanding with inter-disciplinary collaborations which challenge previous understanding of archaeological phenomena and overall bring major benefits to the discipline.

Given the wide range of tools that now fit within the umbrella terms of Visualisation and Virtual Heritage, it is necessary to identify some distinctions. Although there is much crossover, 3D techniques tend to be divided into survey-based and reconstruction-based methodologies. The primary examples of 3D survey are photogrammetry (or SfM) and laser scanning, which use detailed recordings of archaeological objects and sites to create virtual geometry [Zheng 2000; El-Hakim et al. 2007; Karasik and Smilansky 2008]. This process is usually automated, producing a precise representation of reality within determined parameters.

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Reconstruction-based methodologies are instead mostly user generated from a variety of data sources [Barceló 2001]. 3D 'reconstructions' replicate reality through an artistic process, blending together photographic evidence, measurements and inferences. The virtual geometry generated is highly flexible, and allows the inclusion of elements that differ significantly from the present reality. The main advantage is the possibility of "rebuilding" complete sites from partial information. However, while 3D surveys are faithful to the reality they represent, reconstructions can be far removed from it: this can cause issues of precision and lead to misinformation [Eiteljorg 1998, 2000].

This paper discusses the importance of identifying imprecision in reconstruction-based 3D archaeology. It looks at their primary form, 3D approximations – also known as 3D reconstructions, 3D models or Virtual Reality. These terms often have different meanings, but in this context a 3D approximation observes the following criteria:

- User-generated: the virtual geometry is created by an individual and not generated automatically by a computer.
- Hypothetical: it contains at least some conjectural elements.
- Data-driven: the results are in some way quantifiable and recordable.

3D approximations have been used in archaeology as a means to present archaeological data to the public, or to investigate archaeological queries through simulation [for example, Holloway 2000; Dawson and Levy 2005]. Their rise has however been hampered by the growing concern of critics and enthusiasts alike that fear misuse [McCoy and Ladefoged 2009]. While on the surface the real and the digital are one and the same, ontologically they are vastly different: the digital is a representation of the real, and although it may retain many of the latter's behaviours, it can also differ considerably [Skagestad 1999]. The Treachery of Images by Rene Magritte demonstrates this: the painting shows a drawing of a pipe with the caption "this is not a pipe" (Fig. 1) [Magritte 1928-9]. The artist aims to demonstrate that the viewer sees no distinction between a physical object and its representation, but the representation may not be precise or realistic. The pipe may be vastly different from the drawing or it may not exist at all. The treachery of images is the ability of art to convince us something is real when it may be far from reality [Deregowski 1989].

A famous example of deceiving images in archaeology is the Viking horned helmet, as reported by Frank [2000]. The first association between Vikings and horns is from the 1876 production of *Ring des Nibelungen*, courtesy of costume designer Professor Carl Emil Doepler. Vikings of course never wore this item of clothing, but the image was used extensively in books, paintings and advertisements shortly after the production, becoming widely accepted. The public saw illustrations of Vikings with horns and concluded that they had to be real.

Fig. 1. The Treachery of Images by Rene Magritte [Magritte 1928-9]

The complex relationship between real and fake means that 3D approximations must be approached conscientiously or there is a risk of misleading the user [Miller and Richards 1995]. Hence, it is important to understand the theoretical basis of these methodologies, issues that may arise and possible solutions.

This paper will address the key issues with precision and subjectivity in 3D approximations. It will then demonstrate the similarities between 3D approximations, archaeological theory and the scientific method. The problem is quite complex, and as such the primary focus will be on replicability of the results, which is a core (but not the sole) tenant of the scientific method [Marwick 2016]. Further discussion is necessary to fully justify the 3D methodology, including experimentation and hypothesis building.

The paper will also discuss and compare the most used methods for dealing with imprecision. Particular attention will be paid to the use of alternative models, which are the most common solution to the issue.

SUBJECTIVITY AND UNCERTAINTY

The primary problem with 3D approximation recognised by its critics is the lack of precision (for example, [Gray 2016]). While 3D approximations are based on archaeological evidence, it is common for them to include hypothetical elements. In some cases these elements are kept at a minimum to preserve the overall reliability of the evidence, but more commonly the 3D approximations show only the most accepted representation of an archaeological site prior to destruction (for example, Forte and Siliotti [1997]). Nearly unanimously archaeological sites consist of rests of a much larger whole, and the elements added are produced by the designer based on uncertain evidence. This leads to subjectivity and uncertainty, which are inescapable [Lock 2003; Denard 2012b].

A 3D approximation will always be subjective as it is not a perfect copy of a reality but an interpretation of various sources filtered through the eyes of the designer [Molyneaux 1997]. It therefore relies on the understanding of a person, on the availability of information and on the cultural bias at the time of creation [Favro 2006].

Uncertainty is also an inescapable quality of the 3D process. In situ elements have a high degree of certainty, but often 3D approximations rely on comparison with other sites or guesswork [Sims 1999]. The further the approximation is from the archaeological evidence, the more uncertain it is. Yet without the hypothetical elements 3D approximations is simply a less precise approximation of reality, comparable but worse than photogrammetry or laser scanning. The true potential of 3D approximations is the possibility of incorporating hypothetical elements, but the payoff is imprecision.

ARCHAEOLOGY’S RELATION WITH 3D APPROXIMATIONS

While issues of uncertainty and subjectivity need to be addressed, the problem is a much wider archaeological one. The poor relationship between 3D approximations and archaeology is not a novel issue: archaeology has a tendency to ‘adopt’ methodologies and ideas from other disciplines but never fully implement them into its own theory [Okumura and Araujo 2019]. Lycett [2009] discusses the issues encountered in the field of “Geometric Morphometrics” (GM), which was originally developed in evolutionary biology and later adopted in archaeology for lithic analysis. Lycett records that amongst other practical issues such as training and cost, archaeologists tended to avoid GM due to a suspicion regarding the “reality of scientific or quantitative and statistical methods” (p. 80).

Progressively, archaeologists are collaborating with different disciplines to develop new and interesting techniques, and there are certainly examples of biology, mathematics and computer science successfully being integrated into archaeological theory (i.e. DNA analysis, dating techniques and agent-based modelling). However, archaeological theory is still predominantly humanistic, with a focus on interpretation derived from unfalsifiable hypotheses [Dunnell 1982]. Hunt et al. [2001] suggest archaeology is primarily based on systematic empiricism, which consists of generalisations based on observations without the deductive role of theory. This produces interpretations that can never be absolutely true or scientific. A more rigorous scientific method can aid communication between disciplines (Fig. 2).

At the very base of any scientific exploration we have the Hypothetico-Deductive method, which can be simplified to:

> *“[…] a theory, or more specifically a sentence of that theory which expresses some hypothesis, is confirmed by its true consequences.”* [Andersen and Hepburn 2015]

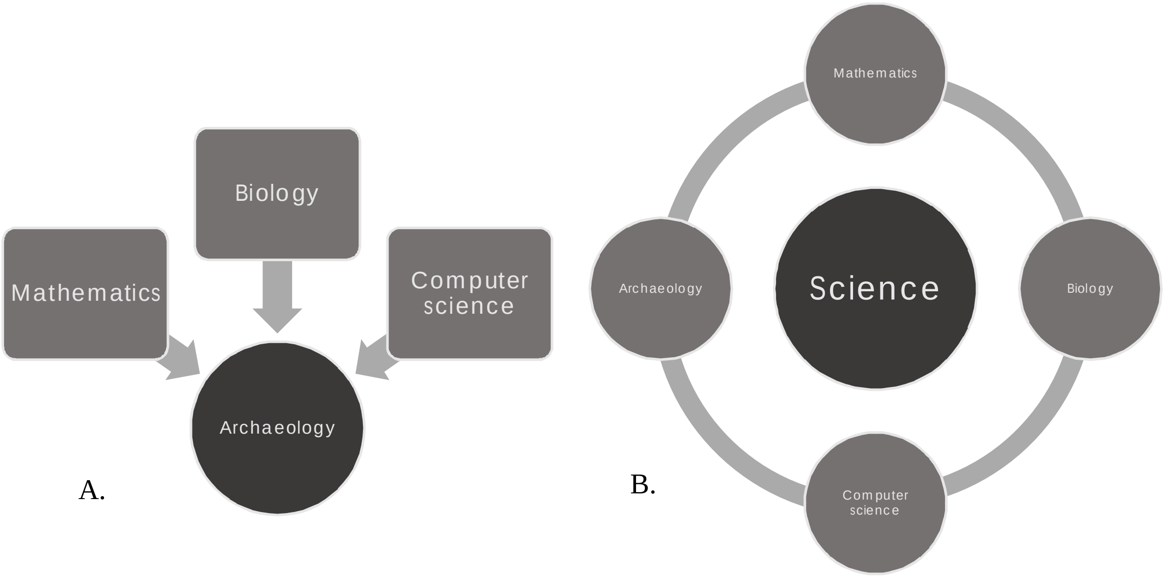

Fig. 1. Archaeology as adoption (A) and as belonging (B)

Archaeological interpretation follows this rule: any theory that is presented must be congruous with the evidence available [Hempel 1966]. Should the evidence change, the theory should be allowed to change accordingly.

The theory cannot therefore be immutable, nor can it ever be definitive. It can allow for elements such as subjectivity and uncertainty, and in fact it requires them to function: an archaeological theory is produced by an archaeologist (a subject) and it represents the best possible interpretation based on evidence (uncertain).

A practical example is the issue of temple roofing in the Maltese Neolithic, which has been amply discussed based on unfortunately scant evidence [Trump 1966; Xuereb 1999; Torpiano 2004, 2010]. The roofs of these prehistoric temples could have been made of stone or wood, and evidence subsists for both hypotheses [Trump 1971]. Various authors have argued for one theory over another based on the limited evidence, but an absolute solution is impossible [amongst others, Ceschi 1939; Evans 1959; Bonanno 1988]. As each author adds their own biases to the theory and due to the limited evidence, this archaeological theory remains subjective and imprecise. Nonetheless, it is an important discussion that can fit within the scientific method.

Archaeology and 3D approximations are therefore not too dissimilar, as they both require uncertainty and subjectivity. Shanks [1997] argues (albeit on the subject of photography):

> *"Consider archaeology: a statement about or image of the archaeological past is not strong and good because it is true or objective; but because it holds together and makes sense when interrogated it is described as objective."* [Shanks 1997, p.82]

While inescapable, subjectivity and uncertainty can be minimised through interrogation and comparison to the evidence.

HYPERREALITY

Imprecisions in 3D approximations and archaeological theory derive from the subject they investigate: a hyperreality.

Hyperreality is a term popularised by Jean Baudrillard, although used here with slightly different connotations [Baudrillard 1983, 1988; Horrocks and Jevtic 1996; Forte 2011]. A hyperreality is a reality in which real and fake are so intertwined they are indistinguishable. An example could be 'reality TV', in which scripted elements, real action, editing and acting are so intermingled it is impossible to distinguish machination from true emotion. For

Baudrillard the ‘truth’ of a hyperreality is in no way accessible to a user, the very nature of these realities concealing their true identity. In the current context, a slightly different definition is used, in which hyperrealities are distinguishable if the user has knowledge of the process that created it. Going back to the example, if the viewer had access to a script they would be able to determine some of the elements of the show that are fictitious.

3D approximations are a prime example of hyperrealities: in situ elements, archaeological records, hypotheses and pure guesses are intermixed, creating a reality which is partially real and partially fabricated. With access solely to the approximation, it is impossible to determine its precision.

Yet hyperrealities are not only a 3D problem, they are lurking in all archaeological theory. An archaeological interpretation is a mix of in situ evidence and hypotheses, and without access to the archaeological records it would be impossible to determine the validity of a theory. For example, the description of a Neolithic Malta funeral procession in the seminal Malone et al. [2009] *Mortuary customs in prehistoric Malta* blends archaeological reports, interpretation and hypotheses to create a first person account of burial practices. The narrative is compelling and evocative, but it would be impossible to determine its precision without access to the site report published in the preceding chapters.

The processes of theory building and 3D approximation are very closely related (Fig. 3). The aim is identical: accessing knowledge of a lost past reality (a historical period). The ‘archaeological past’ is an inaccessible reality, which can never be completely known [Lock 2003]. Parts of it are however still available in the form of archaeological finds, which provide clues on the composition of the past. The archaeological finds are replicated in the archaeological records and literature, which provide constraints for archaeological theories. Once established, theories and approximations feed back into the literature.

A good example of this process is the 3D approximation of a Mausoleum described by Pliny, and created by Hermon [2012]. Although no archaeological remains survive, the procedure is based on literary sources and feeds back into the literature through a careful scientific recording of the process and results.

UNCERTAINTY SOLUTIONS

As discussed, 3D approximation is inescapably subjective and imprecise, due to the input of the artist and its hyperrealistic nature.

As for subjectivity, the consistency and validity of the results acts as a failsafe. So long as the results are replicable, subjectivity can be tested and minimised [Bentkowska-Kafel 2012]. The scientific process doesn’t terminate when the approximation is complete, but it is an on-going procedure that improves with subsequent work and replication [Hermon 2012]. Should further results - building upon the approximation - demonstrate an error due to subjectivity, this can be amended and the new results can replace the erroneous ones. This can happen once the research is complete, but also during the approximation process. Gann [2001] highlights the importance of sharing results with other experts to gather feedback: their approximation of the San Agustin Mission was discussed by a team of archaeologists and the resulting model is therefore less subjective (and more precise).

Imprecision is a larger problem. While subjectivity has a smaller impact on the results, imprecisions can multiply. Nicolucci and Hermon [2004] show how each step increases the imprecision, similar to error propagation in statistical analysis. They associate a ‘reliability’ value to each phase of approximation, which steadily decreases with every hypothetical element. Hypotheses are a cornerstone of the scientific method, but without an understanding of their reasoning they can be mistaken for fact. This is particularly true in 3D approximations, as they are generally non-textual and it is difficult to convey complex ideas with limited schematics [Van Gool et al. 2004]. It is therefore necessary to create a system that records the hypotheses and reasoning behind each step of the approximation.

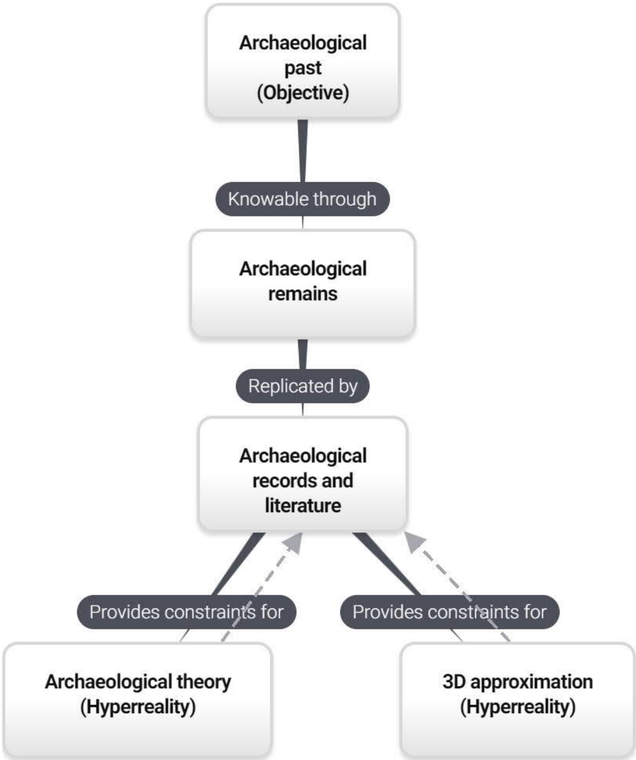

Fig. 2. Comparison between archaeological theory and 3D approximation. At each step more uncertainty and subjectivity are inserted

ALTERNATIVE MODELS

In the literature, alternative models seem to be the most accepted method to record uncertainty [amongst others, Mathur 1997; Huggett and Guo-Yuan 2000; Nicolucci and Hermon 2004; Haegler et al. 2009; Teichmann 2009; Sifniotis 2012]. They are even included in the ICOMOS Charter [ICOMOS 2008]. This practice involves the creation of a number of approximations rather than a singular one. Each approximation has the capability of showing a different hypothesis, therefore giving equal space to possible ideas and reducing the risk of mistaking a hypothesis for fact.

> *"Researchers in general, and archaeologists in particular, should be very careful when using computer reconstructions. Alternative models should be provided to present a range of variables. The past is powerful and any distortions or misrepresentations of it can create havoc."* [Mathur 1997]

Alternative models can be of exceptional use for presenting different theories in publications and exhibitions, when a number of equally interesting hypotheses exist and their discussion is the primary focus of the publication. Sturt et al. [2007] present different versions of the roofing in the approximation of Casa Sollima, Sicily. In this case, the main focus of the article is the original shape of the roofing, and given a number of equally valid possibilities the alternative approximations are necessary.

However, in more general situations, to aid the recognition of uncertainty in 3D approximations a solution must be detailed, easily implemented and congruous with traditional methods. Alternative models unfortunately do not reflect these needs. Presenting multiple scenarios allows for the main theories to be explored, but it leaves smaller issues unanswered. Realistically, a publication or exhibition has space for a limited amount of images. Online libraries and specialised repositories are becoming increasingly common for the storage of 3D data, however even these have limited space compared to the theoretically infinite number of possible variations in 3D approximations. Kensek et al. [2004] created a script to allow users to change various elements of the approximation of the Great

Aten temple at Amarna. With only three variables, the columns alone allow for 105 different scenarios to be presented. There is simply too much data to be presented efficiently and visually.

The act of choosing the possible approximations to display is also highly subjective, yet the end result doesn't record the reasoning for the choices made. Furthermore, production time is increased as alternative models require the creation of many approximations with different details [Sifniotis 2012].

Overall, alternative models show a limited range of possibilities while requiring more space and time to process.

PARADATA AND METADATA

An alternative solution to the issue of imprecision is the use of metadata and paradata [Beacham 2011; Seville Principles 2011]. These are well described in the London Charter [Denard 2012a; also Watterson 2015], but for the purpose of this paper they are defined as

- Metadata: objective technical data associated with the software used.
- Paradata: subjective data derived from the approximation process.

Unlike alternative models, metadata and paradata are usually separate from the approximation itself, often presented as an appendix to a paper, as a separate paper or published in an online repository. The use of these data can be compared to baking a cake. Metadata is the ingredients and oven settings that were used to make the cake, while paradata is the recipe with comments from the chef. An example of metadata and paradata workflow is presented in Demetrescu [2015] and Demetrescu and Fanini [2017], based on the established Harris Matrix used in archaeological stratigraphy. A similar approach is also suggested by D'Andrea and Fernie [2013].

The 3D approximation of the Għajnsielem Road house constructed as part of the FRAGSUS project is an attempt to use metadata and paradata to allow replicability [Barratt 2018]. The project was first shown in an exhibition at the National Museum of Malta, and the associated paper details the approximation steps, the thought process and decisions made, and the overall uncertainty of each element. The article focuses less on the results and more on the connection between sources and the finished product.

Metadata and paradata are an instruction manual for the approximation. They highlight potential issues and allow the approximation to be replicable: by following the metadata and paradata the user should be able to achieve an identical approximation to the one presented. While it is impossible to achieve complete clarity on every aspect of the approximation process, these data allow the recording of all major steps and most minor ones. They allow the designer to explain uncertainty and justify subjectivity [Richards-Rissetto and von Schwerin 2017].

Furthermore, metadata and paradata provide a white-box approach to 3D approximation, i.e. they allow the user to understand how the raw data and the results are related to one another [Pletinckx 2012; Goddard 2014; Demetrescu and Fanini 2017]. Understanding how data was created helps replicate the results [Ducke 2012]. Without access to the internal process, it is impossible to determine elements that could lead to errors or imprecisions due to subjectivity. A white-box approach allows future researchers to compare and contrast results, ultimately concluding which is more valid.

An example is provided below:

a) b)

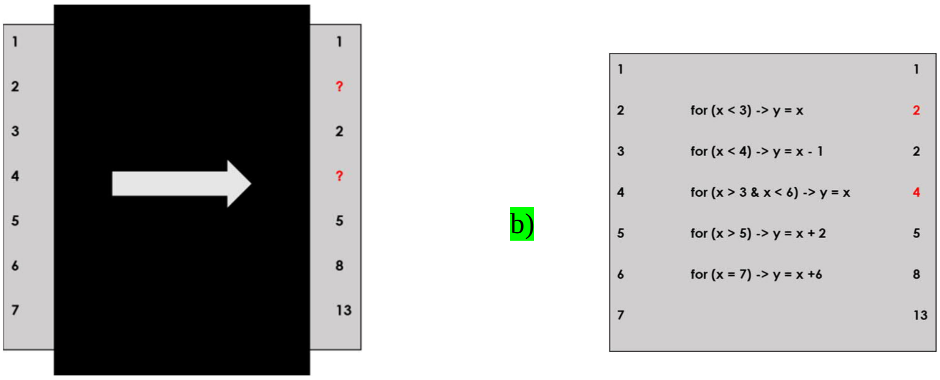

Fig. 3. An example of black box research (a) and white box research (b)

Fig. 4.a) is showing a black-box research. The numbers to the left are transformed into the images to the right using a process that is unknown. By looking at the numbers it may seem that the ones on the right are following the Fibonacci sequence. Fig. 4.b) instead shows the same research but as a white box. It is now clear that the process used is completely unrelated to the Fibonacci sequence. By having access to the process it is possible to determine the overall precision of the results based on the data provided.

As a bonus, the white box approach contains an imprecision which the reader may be able to identify. Only by having access to the process is this possible.

LIMITATIONS

While alternative models are more commonly used, metadata and paradata are more flexible and encompassing. They are also more aligned with traditional publication methods, as they can be included in appendixes or separate traditional papers.

There are however issues that remain unresolved. Metadata and paradata are suitable for publication, but they are less conducive to displays and exhibitions. When presenting 3D data to the general public this methodology is not available due to spatial limitations and the attention of the users. This is in fact a wider archaeological problem, as often exhibitions are forced to present a single narrative based on limited hypotheses. In this case, techniques such as alternative models or pink cement are more suitable [Fletcher and Spicer 1992; Lock 2003].

Other limitations regard a lack of guidelines: metadata and paradata are a relatively novel concept, and as such it is often unclear what they should entail, how they should be presented and their level of detail. Publications such as the London Charter and the Seville Principles have attempted to create a structured approach, but more work is needed [Seville Principles 2011; Denard 2012a].

Finally, an issue that is amply discussed in 3D archaeology is the preservation of these data. With ever changing digital repositories and formats, there is a risk that the metadata and paradata produced will have a limited shelf life. A poignant case is the model of Old Minster of Winchester, one of the first approximations ever created which was thought lost due to changes in formats and being saved solely on an old computer. Luckily, it was recently found and is now available online to view [Reilly et al. 2016].

CONCLUSIONS

The aim of this paper was to present a theoretical background to 3D approximation, comparing it to established methodologies and attempting to position it within archaeological theory.

3D approximation is shown to be replicable, an important element of the scientific method. It is also comparable to archaeological methods. Some issues have been raised, specifically dealing with subjectivity and uncertainty. These have been addressed by recognising the inescapable hold of hyperrealities, but also proposing ways to minimise risks. The most common way of displaying uncertainty (alternative models) has been challenged, and an approach based on metadata and paradata is proposed instead. The main advantages of this solution are the accountability of the results and the possibility of replicating them. Some limitations have however also been identified and require further consideration.

While this is far from a encompassing theoretical background to 3D approximation, it identifies key areas of interest and proposes some new ways of assimilation in traditional archaeological practices.

A NOTE ON TERMINOLOGY

The paper here presented introduces new terminology as part of a more reliable 3D theory, based on terminology used in other scientific disciplines.

The terms '3D reconstruction' and '3D model' are discarded in favour of '3D approximation', following Favro [2006]. 3D reconstruction implies the return to an original, as if the designer had reassembled pieces of archaeological sites into a cohesive whole. This ignores the imprecise and hypothetical nature of the methodology, and may lead users to mistake approximation with certainty.

Similarly, modelling is an ambiguous term that can be confused with scientific models, such as mathematical models. This may also lead to misunderstandings (especially as 3D simulations can work with scientific models) and an overestimation of certainty. The term 3D approximation has been chosen after a discussion with individuals from different scientific backgrounds, as it reflects similar methodologies in other scientific fields. To reflect this change, the term 'modeller' has been replaced with 'designer'. The term 'alternative model' is used to avoid confusion with the literature, although 'alternative approximation' would be more appropriate.

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3D Images as a Source for Analysis and Interpretation of Data Obtained During Archaeological Research

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The will to protect cultural heritage has become an impulse to construct three-dimensional visualizations. Thanks to a computer program and properly manipulated 3D models, scientists can test out their research hypotheses, basing on mutual relations between the models. 3D modeling is a priceless tool when it comes to reconstructing archaeological structures and artefacts as well as analyzing and interpreting the past. It allows creating spatial objects that can be processed in various ways. Digital reconstruction technique is targeted at a vast group of recipients, especially those who are not interested in information about the past presented in a descriptive (verbal) form. Such way of communication requires specific knowledge, including specialist terms, as well as imagination, especially so-called historical imagination. 3D visualization is yet a new narration form in archaeology and complements descriptions. In our society, in which cognitive process an image begins to play a dominant role, popularization of the past with the use of digital reconstruction is particularly important. It is the visuality that determines the way we experience and analyze historical knowledge. An image in the form of a reconstruction is complete, comprehensively narrated, which means there is no room for a deeper interpretation. It is the scholar who defines the vision of a reconstructed structure. That is why an author must keep a critical distance towards their analysis when creating a visual message that provides information on cultural heritage. In order to cover the requirement of reliability when constructing a model, it is advised to follow the standards included in the London Charter. The significance of 3D visualization as a method of presenting research hypotheses will be discussed basing on the examples of digital reconstructions of two settlements from the Early Iron Age, discovered in Lower Silesia in South-West Poland.

Key words:
3D image, visualization, archaeology, reconstruction, 3D model.

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INTRODUCTION

Since the 90s of the 20th century 3D graphics software became a popular visualization tool for cultural heritage [Barceló 2000; 2014; Sylaiou and Patias 2004; Hermon and Kalisperis 2011; Markiewicz 2014; Messemer 2016]. Digital technologies provide contemporary researchers with a set of tools and methods enabling them, apart from verifying the existing research hypotheses and putting forward new ones, to create knowledge about the past by the development and presentation of spatial images of prehistoric buildings.

Reconstruction is the process of constructing the past by an archaeologist, architect or historian, which takes place in the present [Shanks and Tilley 1987]. Creating non-existent archaeological objects with the help of 3D graphics software is not an easy task. In archaeology, the 3D model is based not only on available documentation, but also on presumptions, judgments and predictions concerning the lost area of historical reality. According to the definition of architect S. Kowal [2015], it is an *imaginary model*, i.e. one requiring the creator to make hypotheses which are helpful in understanding the relationship between archaeological monuments, i.e. the so-called *historical certainties*,

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and the creative completion of the image based on imagination and knowledge. The reconstruction of missing, hypothetical or probable data often results from the logic of the system, i.e. the analysis of the object as a whole. These activities are based on the experience of researchers who mainly use analogies to create a model. Three-dimensional reconstruction is therefore a record interpreting the collected documentation.

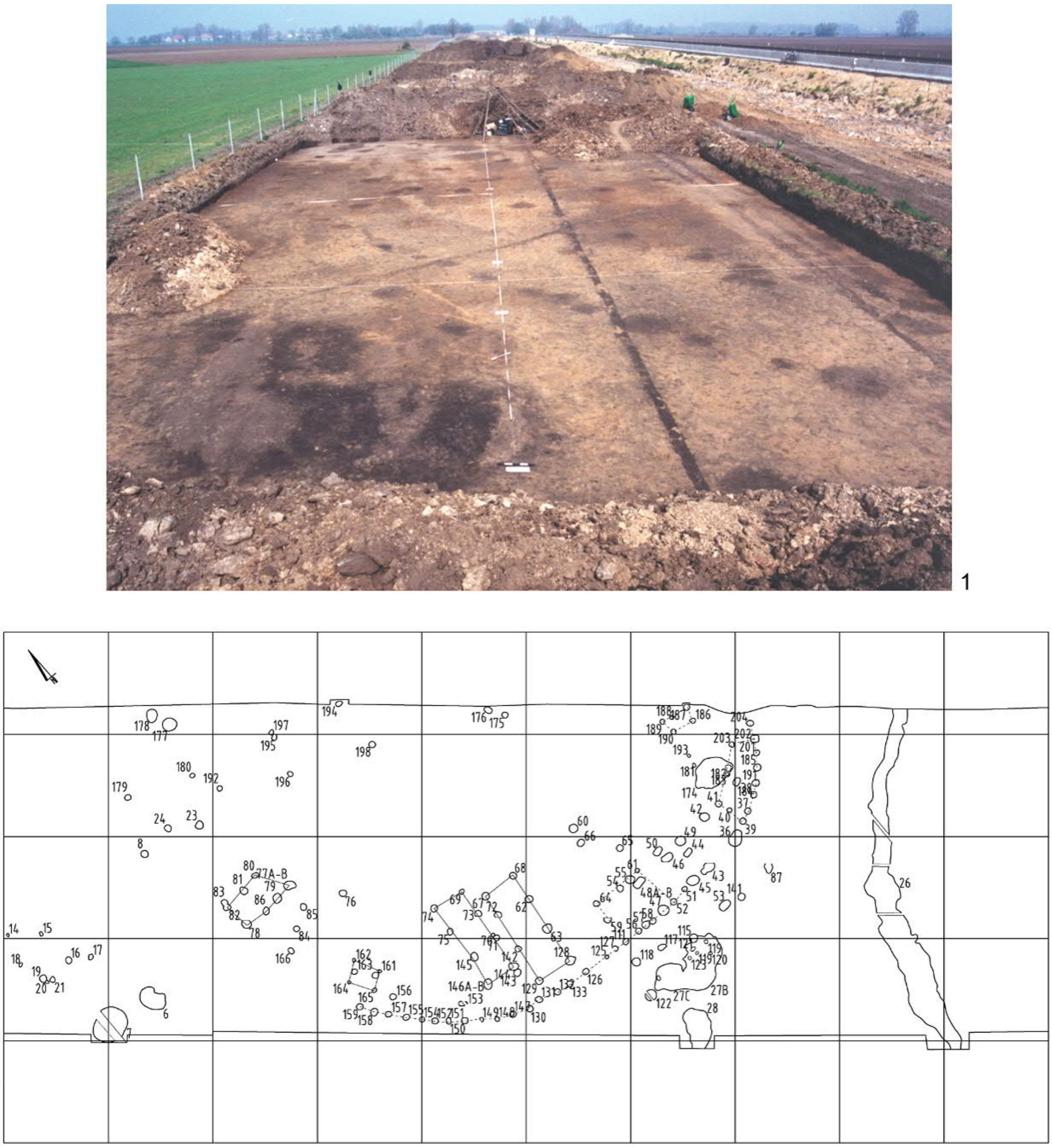
Visualization is a new form of exploring, studying and experiencing the past. Thanks to spatial imaging we can "see more". We expand the area of what is visible considerably. Traditional, written descriptions of artefacts – descriptive narration commonly used in archaeology – are replaced by images more and more often. The process of presenting and popularizing the past in modern society is dominated by images. We experience the past through our discernment or perception [Barceló 2014]. The increased significance of visual presentations in modern society has been defined by two terms: *pictorial turn* according to W.J. Thomas Mitchell [1994] and *iconic turn* according to Gottfried Boehm [1994]. Both terms consist in focusing the attention on the cognitive value of images that somehow stay in opposition to language [Zeidler-Janiszewska 2006]. Presently, people are distancing themselves from what is verbal and turning to what is visual. As Martin Heidegger [1977] stated: *the world is becoming a picture.* The role of pictorial information is constantly growing. 3D reconstruction is a new form of narration in archaeology and complements descriptions [Minta-Tworzowska 2011; Pawleta and Zapłata 2011]. Popularization of the past using digital reconstruction is very important. It is visuality that determines the way we experience and analyze historical knowledge [Koszewski 2015].

The main task for cultural heritage protection given by archaeology is providing the society with knowledge on the past [Pawleta 2016]. The will to protect cultural heritage has become an impulse to construct three-dimensional visualizations. UNESCO's Charter on the Preservation of Digital Heritage[1] [2003]– formulated postulates regarding protection of digital heritage and including 3D visualizations as a way of popularizing knowledge on the past world. To see is also to discover, so a digital image creates a new quality of analyzing the past. It considerably accelerates the process of remembering new visual information and associating it with what the receiver has in his memory [Markiewicz and Kolenda 2015; Kolenda and Markiewicz 2017]. An image constructed with the use of appropriate software becomes a message, a medium that keeps information about the past [Koszewski 2015].

RESEARCH OBJECTIVES

During archaeological excavations conducted in the year 2000 by the Institute of Archaeology and Ethnology of the Polish Academy of Sciences in Wrocław due to the modernisation of a motorway, two settlements from the Early Iron Age, Stary Śleszów 17 and Milejowice 19, were discovered and explored (Figs. 1-2). The sites were located about 4 km from each other. The settlements were outstanding in terms of spatial development. In the area of the settlement in Stary Śleszów a circular structure surrounded with a fence was discovered. Within the structure there were buildings in post construction. It was an inhabited, visibly separated part of the settlement [Kopiasz 2003; Buchner 2018]. A similarly separated part yet considerably larger, was discovered at the site in Milejowice [Bugaj et al. 2002; Bugaj and Gediga 2004; Bugaj and Kopiasz 2006]. The settlements were probably inhabited by people of high social or economic status. The situation is consistent with tendencies observed in the whole Hallstatt culture, where significant changes in social structure took place [Bugaj and Kopiasz 2006].

[1] http://portal.unesco.org/en/ev.php-URL_ID=17721&URL_DO=DO_TOPIC&URL_SECTION=201.html (access: 14.09.2019)



1

2

Fig. 1. The settlement in Stare Śleszów 17: 1) excavations; 2) site plan

Preparing 3D visualizations of the settlements discovered at the sites of Stary Śleszów 17 and Milejowice 19 were part of the project „Spatial-functional structures of Early Iron Age settlements from Silesia in a social aspect”[2]. The aim of the project is to prepare models of social structure of the settlements basing on an analysis of spatial and functional organization (GIS analyses) and their 3D reconstruction. Visualization of the settlements was prepared on the basis of an analysis and interpretation of source material, according to the directions given in the *London Charter*[3].

[2] The project is financed by the National Science Center (Opus 9; No. 2015/17/B/HS3/01314). The project director is Professor Bogusław Gediga.

[3] http://www.londoncharter.org/fileadmin/templates/main/docs/london_charter_2_1_en.pdf (access: 14.09.2019)

Fig. 2. The settlement in Milejowice 19: 1) excavations; 2) site plan

The document contains methods providing the highest quality of 3D reconstructions and verification measures that allow checking historical reliability of 3D models [Beacham et al. 2008; Bentkowska-Kafel 2008; Denard 2012]. The visualizations were made using *Autodesk 3ds Max*[4] 3D design software with *V-ray* rendering engine.

[4] https://www.autodesk.com/products/3ds-max/overview (access: 13.12.2019)

METHODS

The work over the three-dimensional reconstruction of settlements in Stary Śleszów and Milejowice was started by a thorough examination of sources. The examination consisted of an analysis of available archaeological documentation (site plans, building plans, drawings, photographs and description: examination log, building catalogue) and publications on early Iron Age construction [Niesiołowska-Hoffman 1963; Kopiasz 2015; Gralak 2017]. At this point, the important issues included: consultations with specialists, searching for iconographic analogies, available in subject-matter literature and for publications presenting various types of reconstruction of Hallstatt buildings, both in traditional and in digital form – i.e. websites.

The examination revealed certain para-data, i.e. an amount of knowledge that can be gained during virtual reconstruction, in the process of analysis and interpretation of source material and via analysis of missing data [Bentkowska-Kafel 2008]. All para-data that became a foundation for further works over the digital reconstruction of the architecture of the settlements were collected in a digital catalogue.

The following stage involved the construction of three-dimensional models of individual buildings (Figs. 3-4), basing on previously digitalized and vectorized plans (scaled 1:100 and 1:20). Also models of e.g. animals, plants and fencing were prepared. Modelling of the items was made via software used for creating 3D graphics. Along with modelling, the process of creating textures, i.e. photographs previously prepared by means of software for creating raster graphics *Adobe Photoshop*[5]. The reconstruction of settlements in Stary Śleszow and Milejowice involved e.g. photographs of old timber, stones, earth, sand, and animal fur. Upon completion of the modelling process, the textures were laid upon particular elements of architecture.

The further stage of preparing the 3D visualization involved introduction of an adequate model of lighting, light reflection and retraction. Another step was setting up virtual camera settings. Thus, we have fixed the so-called observation points, which influence further perception of entire visualization by the recipient.

The last stage of the work over the digital reconstruction of the settlement is rendering and saving complete digital illustrations. Rendering consists of creating an image on the basis of a model that was covered by photo-realistic texture. During this process, the software analyses the interaction between matter and light. The objective of such procedure is to present the model in the most realistic way possible. The visualization of the architecture of the settlements was done via *V-ray* (*Chaos Group*)[6] – a rendering engine. Thus, the resulting image is reflected in a more realistic way. It is often stressed in the literature on the subject that the photorealistic visualizations convey false impressions that the object presented really exists or that the data used as a basis for the reconstruction provide a lot of reliability [Strothotte et al. 1999, 16-17]. That is why it is necessary to provide a description of the reconstruction process and show all hypothetical elements so that the viewers can interpret the image presented to them correctly. In order to avoid the problems with the loss of data, the individual stages of visualization were recorded according to the principles of the London Charter[7].

As it was noticed before, all para-data that became the basis for individual works on digital reconstruction of settlement buildings were collected in a digital catalogue. All data, such as photographs, drawings, plans and descriptive documentation of excavations were placed in respectively named folders. During the entire reconstruction process, a so-called „reconstruction log" was filled (Fig. 5). It contains the following data: date, number of hours devoted to a given activity, documentation used, references, and description of the activity, hypotheses and comments, print screen from the Autodesk 3ds max program, file name with visualization (record from a given day). The best way to collect data related to the process of reconstruction of historic objects is to create databases. A model example is the project „Virtual Reconstructions in Transnational Research Environments – the Portal: Palaces and Parks in Former East Prussia" [Kuroczyński et al. 2016]. Compared to the above-mentioned project, the way in which we archived data and described the course of the reconstruction process is quite simple, but it fulfills its most basic tasks. Unfortunately, the catalogue made as part of the project is not available on the Internet. Access to it is limited only to researchers participating in the project. Therefore, in the monograph on the layout of

[5] https://www.adobe.com/products/photoshop.html?promoid=PC1PQQ5T&mv=other# (access: 13.12.2019)
[6] https://www.chaosgroup.com/vray/3ds-max/b?utm_expid=.xI2yN5iRQYmvXIDxsDrAhg.1&utm_referrer=https%3A%2F%2Fwww.chaosgroup.com%2Fvray%2F3ds-max%2Fb (access: 13.12.2019)
[7] http://www.londoncharter.org/ (access: 13.12.2019)

building settlements from Stary Śleszów and Milejowice, the reconstruction process will be presented in more detail and hypothetical elements will be specified.

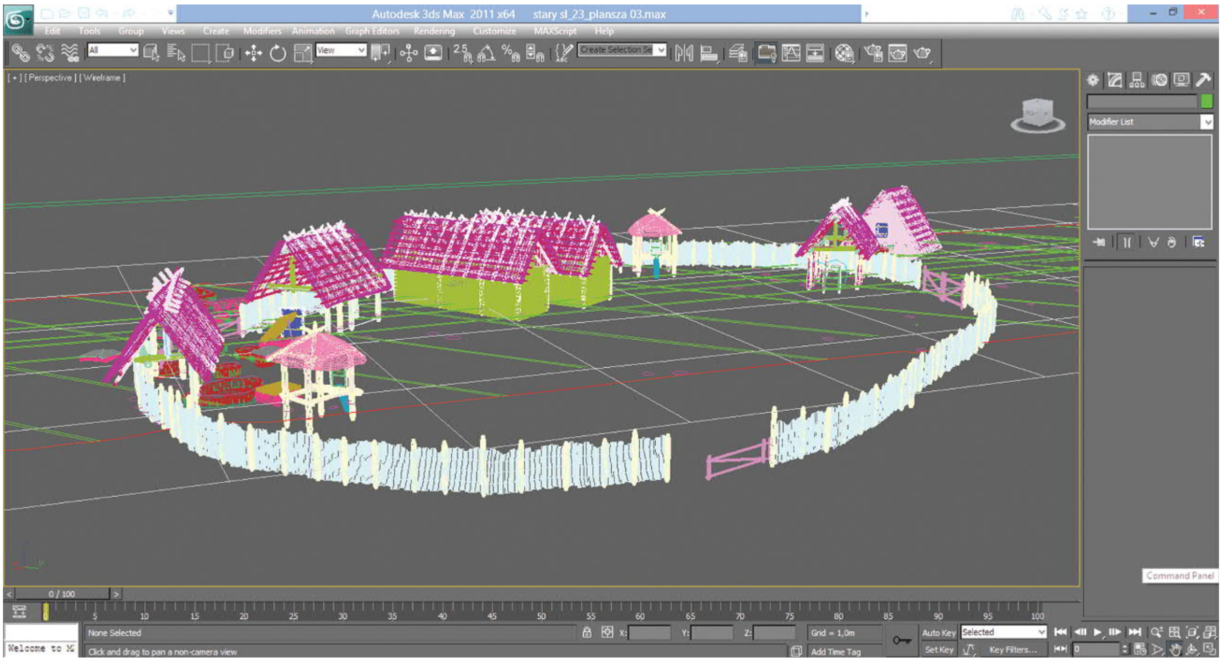


Fig. 3. Three-dimensional model of settlement in Stary Śleszów 17 (by M. Markiewicz)

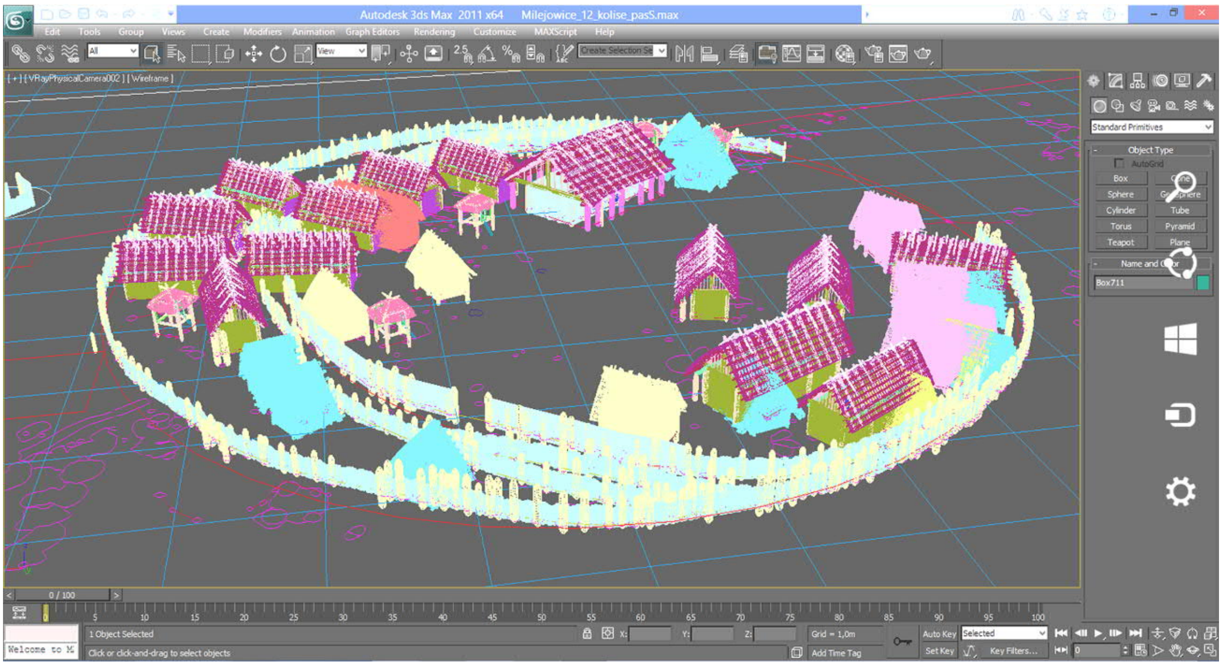


Fig. 4. Three-dimensional model of settlement in Milejowice 19 (by M. Markiewicz)

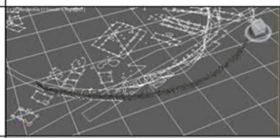
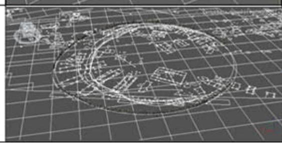
DATA/ DATA	LICZBA GODZIN/ NUMBER OF HOURS	DOKUMENTACJA/ DOCUMENTATION	LITERATURA/ REFERENCES	OPIS CZYNNOŚCI/ DESCRIPTION OF ACTIONS	HIPOTEZY I UWAGI/ HYPOTHESES AND NOTES	PRINT SCREEN	PLIK/FILE
20.06.2018	6	plany: 1: 500, 1:100, 1:20; plan CAD; fotografie; dziennik badań; katalog obiektów	Kopiasz 2004, 31-60 Bugaj, Kopiasz 2006, 175-207	Studiowanie artykułów, dokumentacji, konsultacje	Budynki nachodzą na siebie. Trzeba wyszczególnić fazy zabudowy.	-	-
28.06.2018	1	plan CAD katalog obiektów	Kopiasz 2004, 31-60	Poprawianie planu (usuwanie zbędnych elementów, obiektów o innej chronologii: unietyckie i współczesne)	Na planie obiekty o innej chronologii. Obiekty k.unietyckiej i współczesne.	-	Milejowice_01.max
28.06.2018	2	plan CAD katalog obiektów	Kopiasz 2004, 31-60	Analiza zabudowy kolistego założenia położonego na pasie S.	Co najmniej 3 fazy zabudowy. Na pasie S: 27 budynków słupowych; 10 budynków wziemnych, studnia	-	Milejowice_01.max
28.06.2018	2	plan CAD katalog obiektów	Bugaj, Kopiasz 2006, 175-207	Modelowanie ogrodzenia I			Milejowice_02.max Milejowice_03.max
29.06.2018	2	plan CAD katalog obiektów	Bugaj, Kopiasz 2006, 175-207	Modelowanie ogrodzenia I Ustawienie parametrów renderowania, oświetlenia, kamer			Milejowice_03.max

Fig. 5. A part of the "reconstruction log" containing data about the visualization process

RESULTS

3D visualization supports interpretation of the research results and functions as a presentation of data gathered during excavations. The digital illustration, constructed with the help of appropriate software, becomes a message, a carrier of information about the past. It is through contact with reconstruction that the viewer makes an effort to search for meanings and values of a given cultural heritage resource [Szrajber 2016].

In the case of both settlements, in Stary Śleszów and Milejowice, we can distinguish phases of construction of the circular structures. The phases are confirmed by: close distance between the distinguished buildings and superimposition of the buildings.

Basing on mutual relations between particular objects and suitable manipulations with 3D models, two phases of construction of the settlement in Stary Śleszów and three phases of construction of the circular zone in Milejowice were confirmed.

The visualizations of settlements in Stary Śleszów and Milejowice (Figs. 6-9) contain a small number of hypothetical elements. A thorough investigation of the sources guarantees that the 3D reconstructions are historically plausible. Proper archiving and recording of the reconstruction process was also ensured so that the collected data could be verified, updated and corrected easily.

Fig. 6. 3D visualization of a circular structure surrounded with a fence in Stary Śleszów 17 ¬ (by M. Markiewicz)

Fig. 7. 3D visualization of buildings in Stary Śleszów (by M. Markiewicz)

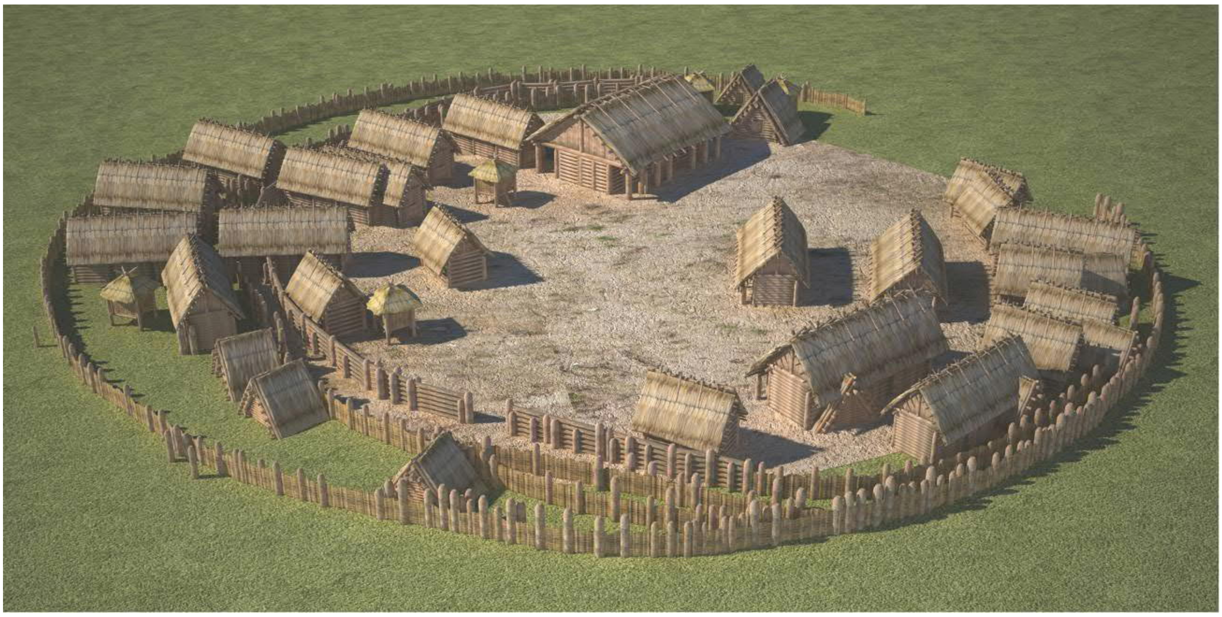


Fig. 8. 3D visualization of a circular structure surrounded with a fence in Milejowice 19: (all objects discovered during excavations). By M. Markiewicz

Fig. 9. 3D visualization of the first phase of buildings in Milejowice 19 (by M. Markiewicz)

CONCLUSIONS

Presenting the results of archaeological research carried out on the settlements in Stary Śleszów and Milejowice in the form of a visual message is particularly valuable: it allows verifying the gathered data and supports the interpretation of the research results. The choice of the reconstruction in the form of a spatial image resulted from the fact that the software to develop 3D graphics is today an invaluable and increasingly popular tool for visualizing of cultural heritage [Barceló 2000]. To see means also to learn, so the digital image is designed for a large group of viewers and it provides added value to the analysis of the past. It also significantly improves the process of remembering new pictorial information. Another advantage is that the developed model can get critical feedback and it can be corrected in accordance with newly gathered data or technical possibilities [Markiewicz 2014]. However, it should be noted that subsequent variations and versions of the 3D model may cause a problem with information overload. Each time the next visualization of the same object must be described and explained in the scientific publication.

As already mentioned, the proposed visualization is addressed to a wide audience. It can therefore be read on several levels. First of all, it is a standalone message which exists independently of narrative information. In this form it is addressed to recipients who are only marginally interested in the past and the ways of its presentation, and limit themselves to obtaining general information about the archaeological object and its form. Thus, it is a proposal without additional information about the process of data acquisition and verification. The next level is extended by narration. Individual virtual images can be combined with information describing the preserved elements (authentic) and those created on the basis of the researcher's knowledge (hypothetical). Depending on the degree of interest of the recipient, this image may be supplemented with additional information (narration) concerning the stages of visualization creation, methods of verification of the source data and the existing research hypothesis. Correct reading of the information contained in the image depends primarily on the knowledge possessed by the recipient and only thanks to it can one count on the correct reception of the content of the visualization. Two levels of reading visualization are addressed to the general public, in order to popularize the knowledge about the past and raise awareness of the matter of protection of cultural heritage [Markiewicz and Kolenda 2015]. Currently, our project is still working on the second level of reading visualizations, i.e. creating a description of hypothetical elements and presenting the process of collecting and verifying collected data.

Showing the structure of the settlement in a spatial way helps the recipient understand the message better. The 3D reconstruction of the settlements was presented so that the recipient could read the information as the sender-researcher intended. A clear visual message does not require any special preparation in order to be read. An image in the form of reconstruction is complete, entirely explained, which means it does not leave room for further interpretation. It is the scholar who defines the vision of a reconstructed building. That is why the creator has to keep a critical distance towards the analysis when preparing a visual message that contains information on cultural heritage. It should be remembered, however, that on the basis of similar sources, different visions of the same archaeological object can be created. The process of data interpretation and processing depends on the researcher, which means that the created final digital model is marked by decisions taken by the creator [Szrajber 2014]. Wrong decisions contribute to the spreading of false iconographic message. Presently, much attention is paid to providing scientific reliability of archaeological reconstructions [Koszewski 2015; Münster et al. 2016]. In order to ensure it, one should follow the postulates contained in the mentioned documents: London Charter and UNESCO's Charter on the Preservation of Digital Heritage.

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Deferred Executions: Digital Transcriptions of Unbuilt Architectural Projects

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The present paper proposes some considerations on methods aimed to the construction and visualization of 3D digital models based on design drawings of unbuilt architectures. In this case, some of the Francesco Cellini's projects were analyzed. The tested procedures considered the most suitable visual language to communicate the different degrees of verisimilitude (from the symbolic to the iconic) in the process, allowing to manage the quantity and quality of information throughout the whole process, from data acquisition to final visualization. Various variables were considered, such as: the type of recipients, the quantity and quality of the starting data and the possible interpretations of the available sources according to the theoretical assumptions considered. The final product is a geometric and information model in which both the steps of interpretation and the final result can be identified. In order to describe the type of realized model and aiming at the establishment of a shared methodology in the field of virtual reconstructions of unbuilt architectures the experimentation of a "Level Of Reconstruction" value (LOR) is proposed, in analogy with the concept of Italian LOD applied to "Building Information Modeling" BIM. LOR is a function of both the level of detail and metric/geometrical accuracy and the level of reliability of the reconstruction itself. The proposed LOR, at this stage of the research, has four levels (A, B, C, D) that are distinguished by graphic codes created on the basis of both real and hypothesized data. The ongoing research has started on drawings by Francesco Cellini but it is expanding the case studies by acquiring other examples, as the unbuilt projects of the ABDR firm in Rome (Italy).

Key words:
Digital Reconstruction, Unbuilt Architecture, Design drawing, Francesco Cellini, Level Of Reconstruction.

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INTRODUCTION

There is a cultural heritage consisting of design drawings of the twentieth century architecture that are represented through traditional tools and techniques. This heritage testifies to a way of thinking and designing that is not yet influenced by the transformations of the digital era. This contribution concerns drawings of unbuilt architecture. They contain an intangible heritage characterized by different knowledge: that of the history of architecture, of the history of construction techniques and technologies, of the development of the theoretical thought of the belonging era, of the designers' individual poetics.

Currently many authorities, public and private institutions keep architectural drawings and make them accessible through digital archives, organized by collections, according to standards of cataloguing and filing adhering to standardized indications, showing original images sometimes at high resolution, sometimes at low resolution. Consider, for the Italian architecture at the Michelucci fund, the Ridolfi collection, the archive of the Accademia di San Luca, the MAXXI[1] archive in Rome and the drawings archive of the IUAV[2] in Venice. Moreover, there are the multiple digital interpretations of architectural projects proposed by numerous exhibitions or conferences in recent years.

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[1] Museo nazionale delle arti del XXI secolo ("national museum of 21st-century arts")
2 Istituto Universitario di Architettura di Venezia ("higher institute of architecture of Venice")

The presented research started on some reflections that took place after an educational experimentation at the Department of Architecture of Roma Tre, in the Course of Representation Techniques, where the students have interpreted and reconstructed in a 3D environment some projects of the architect Francesco Cellini. All the projects were unbuilt except for one. The aim was to make students understand that drawing is a critical tool with numerous valences. An important issue emerged: how to communicate the different levels of reconstruction that can be achieved starting from the archival drawings, considering that the information concerning each project is different in data quantity and quality?

Thus, research began on the digital accessibility of archival collections and on the possible methods for interpreting and returning the available data and information. The case study of Francesco Cellini's drawings of non-built architecture was studied in greater detail. Part of the reflections are contained below and are divided into four sections: (a) the object of the experimentation and its classification in the graphic culture of the design drawing; (b) the definition of the graphic message in digital reconstruction; (c) the interpretative value of the operator and the reference to the restoration theories; (d) the proposal of an LOR level, i.e. “Level Of Reconstruction”, which allows to identify levels of iconicity and to establish graphic codes for the different levels of interpretation. The first three sections indicate the theoretical process developed to support the last one that shows a first proposal for a protocol to visualize the experimentation.

THE OBJECT OF EXPERIMENTATION

Francesco Cellini's (*1944) drawings are the place of experimentation. Cellini graduated in Architecture in Rome in 1969. During the university period, he frequented Alessandro Anselmi, Manfredo Tafuri and Carlo Aymonino. From 1980 to 1982 he worked as an exhibition designer and curator with the Architecture sector of the Venice Biennale, and from 1982 to 1985 with the Visual Arts and Cinema sectors. He is a member of the editorial board of the magazine "Casabella". Among his works it is worth mentioning: Houses for workers at Maccarese, Rome, in collaboration with Alessandro Anselmi (1971); a project for Piazza dei Cinquecento, Rome (1982); a project for the new Faculty of Architecture for the University of Roma Tre at the former abattoir in Testaccio, Rome (1999); a project for new residential tipology, at Bufalotta (Rome) with P. Orsini and G. Raggi (1999); a renovation project for Piazza Augusto Imperatore (under construction) and the exhibitions "The Project of the Roman Group at the XVII Triennale of Milan[3](Rome, 1989). He has been a member of the National Academy of San Luca since 1993 and President for the two-year period 2019-2020. He is a Roman architect, great draftsman, influenced by the Roman school painter (such as Lorenzo Vespignani) and he is a scholar of Mario Ridolfi. The repertoire of drawings of non-constructed projects covers a period from the eighties of the twentieth century to the early years of the twenty-first century. The projects were developed for architectural competitions so they present different degrees of definition. For this reason it was taken into account a fundamental concept: the transmission of the characteristics of a projected architectural work is entrusted to its graphic editing, where it is intended as the communication of the architectural project in all its articulations: from the sketch of the initial idea to the executive drawings for the construction. The entire first phase of the research was dedicated to the analysis of the drawings and to the interpretation of the raw data and information they contained in order to better organize the three-dimensional reconstruction. The designer's poetics and language have also been defined. It was possible to distinguish some categories of drawings composed by different types of graphs (Fig. 1).

[3] Unpublished materials for the exhibition. The imagined cities. A trip to Italy. Nine projects for nine cities. Rome. The political city. The Parliament and the new Ministries", in collaboration with Cornell University College of Architecture, Art and Planning and University La Sapienza of Rome, curated by F. Moschini, R. Einaudi and A. Capuano, at A.A.M. Architettura Arte Moderna

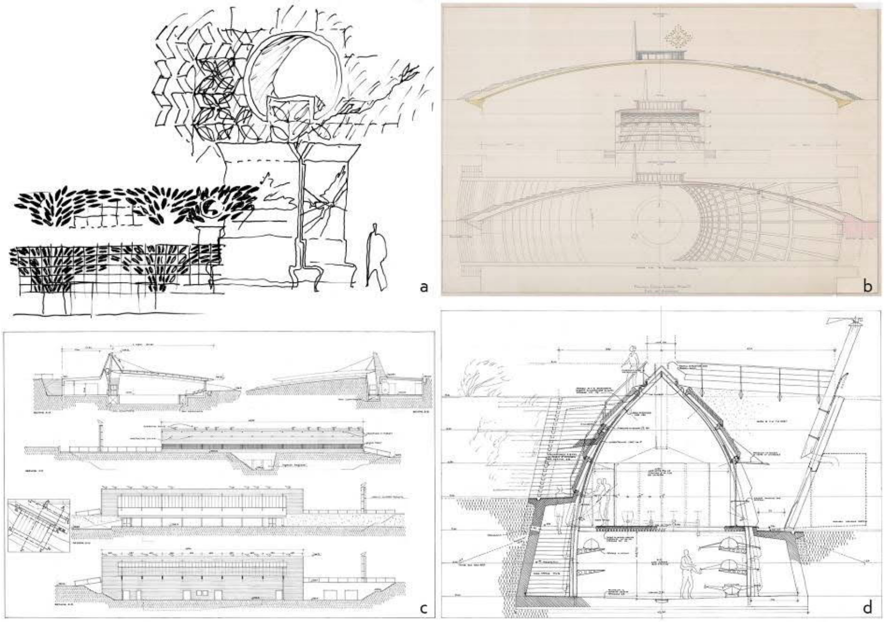


Fig. 1. Drawings by Francesco Cellini: a) preparatory drawing for Piazza dei Cinquecento, Roma (F. Cellini); b) preliminary drawing for Ponte dell'Accademia, Venezia (Università Iuav di Venezia - Archivio Progetti); c) definitive drawing for a pool, Baschi (F. Cellini); d) executive drawing for rowing facility, Baschi (F. Cellini)

The Italian legislation was also used as a reference. An example of systematization follows: (a) graphs aimed at the designer himself for the volumetric/functional/formal setup of the project idea; (b) graphics for the communication of the work conceived by the designer with the aim of transmitting information to the client for the verification of its satisfaction; (c) graphics intended for the Public Administration responsible in order to ascertain the compliance of the project with the current planning regulations and the issue of authorizations and building licenses; (d) graphs intended for the contractor for the construction of the work itself. The first category includes the *preparatory* drawings for the design of the project, the reference drawings, the conceptual sketches and ideograms; the second category includes the *preliminary* drawings that express the feasibility of the intervention in a given context, the presentation of the chosen design solution and the possible alternatives. These drawings establish the potential development of the chosen solution in the success levels of the final and executive design, therefore they visualize the project according to established limits. The quality and quantity of both the contents and graphic drawings depend on the potential development. The following contents, included in this phase, emerged: historical-archaeological, environmental-landscape, topographical, ecological, hydrological, geotechnical. It is important to underline that the elaborates depend on the design choices and the graphic/architectural culture of the designer, therefore the prefigurations through the drawing of the morphological, typological and technological solutions are at the designer discretion. This is why data and information are often not congruent with the logic of those who analyze them and it must also be said that the case study does not present the development of a project according to the different phases of the building process, but each analyzed project belongs to a distinct phase. During the *definitive* design phase, control drawings emerged. Their object of communication consists in narrating the project idea, now dimensioned and architecturally defined into the given environmental context. Here it has to be distinguish two areas of development of the drawings: (a) building authorization drawings; (b) drawings for the technical-economic evaluation of the project needed to set the lines of development for the executive level. The drawings must also express, through appropriate coded symbols, all the information useful for the control of the technical planning regulations. In general, the drawings of the *executive* phase must respect the indications obtained from the previous level and should offer a both parallel and transversal reading for different areas of study such as: architectural, structural, technological/plant engineering. So the drawings available presented the project starting from an overview in plan, elevations, and sections on a scale of 1:100 or 1:50, until the presentation of the construction detail also in a scale of 1:1. The aim was to transmit the project in its constructive specificity and to highlight: (a) the techniques to be adopted for its realization; (b) the operational aspect of the construction phases [Farroni 2009]. The results of the analysis phase are shown in the table where, for each category, the graphic apparatus is accompanied by documents that specify the characteristics of the contents. In the research this information was considered as non-graphical input (Fig. 2).

GRAPHIC	preparatory	preliminary	definitive	executive
TECHNICAL		X	X	X
EVOCATIVE	←			→
NON GRAPHIC	←			→

Fig. 2. Type of information at different stages of the design process.

GRAPHIC MESSAGE DEFINITION IN THE DIGITAL RECONSTRUCTION PROJECT

For the definition of the graphic message in the digital reconstructions of the unbuilt architecture, the theories by A. Moles [1969] and G. Anceschi [1992] have been taken into account. In fact, according to what Moles reports, in the message there are two points of view that correspond to two types of information: (a) semantic point of view; (b) aesthetic point of view. He argues that the nature of the reaction to the message distinguishes the semantic point of view and the aesthetic point of view. In the research it was considered appropriate to equalize the different graphic phases, corresponding to the levels of architectural design process, at the semantic point of view by Moles, while the aesthetic point of view was used to manage the aesthetic value recognizable in some drawings, which are included in the communication of the project. In fact, the semantic point of view is distinguished by a logical character, recognized rules and coded symbols. Moles says that the semantic point of view is a question addressed to the external world in relation to its state and its material evolution, which serves to prepare a decision (such as manuals and military orders that carry a semantic information or prepare actions and their modalities). This is also the case for the organization of the technical drawings of an architectural project: they structure the development of the project idea and control its constructive possibilities. Again, Moles argues that the semantic information has a utilitarian, logical character, an expressible structure, which prepares the action of understanding and the methods of implementation; its rules and symbols are universally accepted by the receivers, constituting a standardized code. The information is translatable and switchable. The information of the architectural drawings is translated according to the scale of the representation and is switched into *specific graphic experiences* until their realization. Otherwise, aesthetic information does not refer to an universal repertoire, but to the repertoire of knowledge that is common to the transmitter and the receiver. In this specific case, this type of information is linked to the aesthetic value of Cellini's drawings, thus being able to use the concept of *evocativeness*. (Fig. 3).

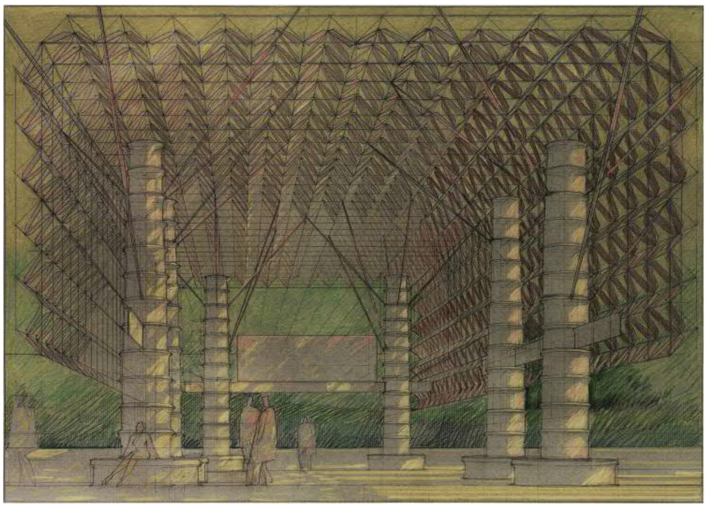


Fig. 3. A perspective drawing by Francesco Cellini characterised by a strong aesthetic value. Project for Piazza dei Cinquecento, Roma (F. Cellini).

As Moles argues, aesthetic information is untranslatable in another language, that is, in another system of logical symbols because this other language does not exist: it is just personal information. It should be emphasized that the aesthetic point of view determines inner states, as shown in the perspective sections drawn by Francesco Cellini. The perspective sections by Cellini are part of the final drawings but are not considered as technical. They present the semantic aspect in the management of the subject, in the relations of balance, of perspective, of the represented objects definition. They also present the aesthetic aspect that is their originality, beyond the phenomenon that Moles considers as redundancy. It is to remember that the latter lets the receiver to recognize the adherence to a style, in the signs and shades, and to constitute a priori knowledge that defines the design style. It also has to be said that the semantic information is addressed to universal aspects and is easily measurable, therefore manageable, while the aesthetic information is random and specific to the receiver and it varies according to the repertoire of knowledge, symbols and a priori structuring. According to Moles theories, in order to support the theory of two coexisting points of view, an external observer is needed. That is, next to the normal source-receiver channel, an auxiliary channel represented by the observer is needed. The observer examines the signals received from the source considering them to be discrete and noise-free, and describes them in a universally intelligible metalanguage [Moles 1969]. In the drawings transcription, the researchers are the observer of Moles' theory.

From the theories by Anceschi reasoning has been made on the object of the representation and on the definition of the visual concept (Fig. 4). It is believed that in virtual reality, the reality is a choice to codify information on both the visual and the interaction levels. In this research, it has been decided to consider only the visual level. D. Marini (a student of Anceschi) speaks of "Degree of Verisimilitude" between the simulated reality and its representation [Marini 2007]. The research faced with a simulated Reality constituted by the real "unbuilt" drawings, a simulated reality that has already been represented. Therefore, the research deals with its representation and with its specific communicative goal. From the theoretical references, it should be noted that the object of representation is the result of a conventional treatment of information. The collection of sources (the drawings) helps to form the visual concept mentioned by Anceschi. The research interpreted the meaning of "visual concept" as the idea (eidos), image, apparition that is created and modified with the acquisition of the sources, the documents that "put before the eyes of the mind" that is complementary to the expression "put before the eyes real and own" (representation). So, an integral vision can be established: a model that can be explored, that is dynamic and practicable, that changes every time new information is acquired. In summary, the important step by Anceschi is that:

> *"The representation and the image consist in a series of operations performed, not on the factuality of reality or even on the actuality of perception but on the always conjectural virtuality of this object/model."*
> [Anceschi 1992]

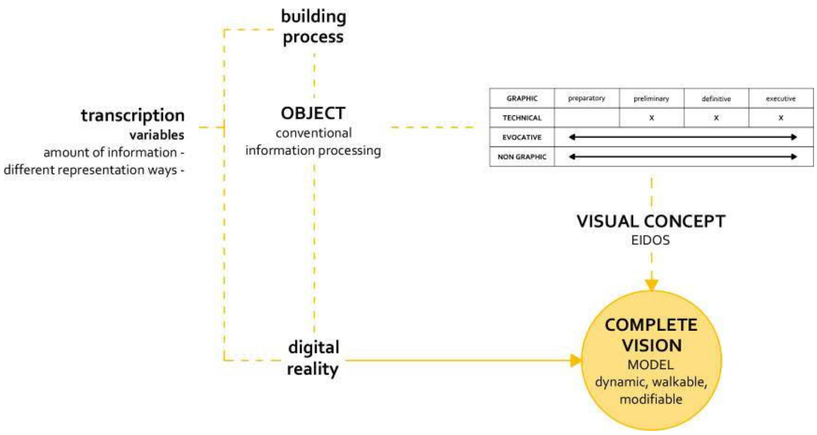


Fig. 4. The idea of Visual Concept in the digital transcription process

THE INTERPRETATIVE VALUE OF THE OPERATOR AND THE REFERENCE TO THEORIES OF RESTORATION

However, the reconstruction process may lead to an object/model that often present incongruent information in its development, some missing parts, some hinted at. In our case, the problem of the "lacunas" emerges, that is, that the design drawings of unbuilt architectures can testify in an incomplete way the work they refer to, thus configuring themselves as the fragments of an artwork to be restored. The interpretation of the project through the drawing has faced choices and considerations. Useful references in the restoration theory were: (1) the concept of "potential unit" by Cesare Brandi [1963] and (2) the concept of "re-integration" by G. Carbonara [1976] which illustrate the limits and potential of reintegration interventions on pre-existences; (3) Umberto Eco's theories that show how drawings can be considered as an "open works" or as a field of interpretative possibilities, that allows a series of always variable readings [Eco 1997]; (4) the concept of "deferred execution" by M. Manieri Elia, according to which the project is the only autograph moment of an architectural work, and every architectural works realized (but also unbuilt) are a "deferred execution" of designer's idea [Manieri Elia 1991]. By transferring these concepts to the drawings of unbuilt architecture, it is possible to consider the drawing interpretation as a sort of digital "laboratory" through which it is possible to analyze drawings details, their graphic and textual notations, to simulate the generative process of the form conceived by the designer.

DISCUSSION: PROPOSAL FOR A LOR LEVEL: LEVEL OF RECONSTRUCTION

It should be emphasized that for the definition of a method for digital reconstructions, the research identified three different levels of the drawings: the archival drawings intended as "zero level", the digital models intended as "transformation level" and the new elaborations intended as "level of completion/reintegration". The use of 3D modelling is chosen as the tool is able to decline the different opportunities offered by the interpretation, allowing their feasibility verification (Fig. 5).

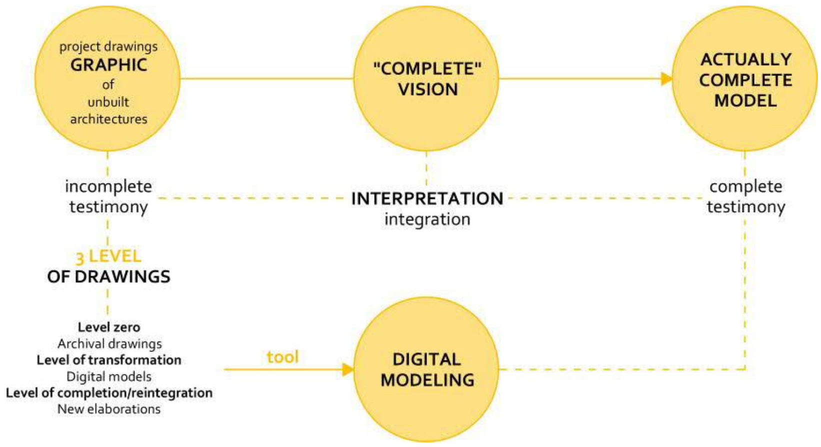
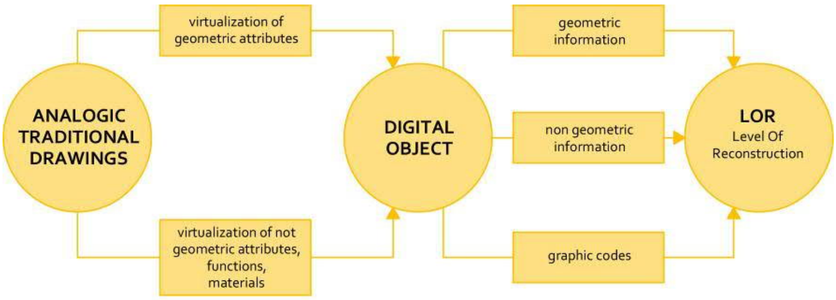


Fig. 5. The role of the interpretation phase into the reconstruction process

The drawings analysis and the considerations made on the interpretations have made clear the need to define a LOR chart, i.e. Level of Reconstruction chart, which would put the visual concept and its integrations into a system. The LOR is defined by geometric and non-geometric information and graphic codes: for both the reconstruction based on data and hypotheses. According to some references on Pavan's "Building Information Modeling" (BIM) theory [Pavan et al. 2017], it is possible to report this scheme that is constituted by: the materials archive drawings (traditional analogical drawings); the virtualization process as the definition of geometric and non-geometric attributes; and the production of a digital object characterized by geometric features/non-geometric information and the definition of a graphic code (Fig. 6).



input	GRAPHIC	preparatory	preliminary	definitive	executive
input	TECHNICAL		X	X	X
input	EVOCATIVE	◄────	────	────	────►
input	NON GRAPHIC	◄────	────	────	────►
Level Of Recontruction (LOR)	LEVEL	A	B	C	D
Level Of Recontruction (LOR)	GEOMETRY	proportionate volumes	measured volumes	measured volumes	measured volumes
			wall thickness	wall thickness	wall thickness
					wall stratigraphy
					technological detail
	INFORMATION		function of spaces	function of spaces	function of spaces
				materials	materials

Fig. 6. The definition of LOR in relation to the different type of design drawings

Level Of Recontruction (LOR)	LEVEL	A	B	C	D
	GEOMETRY	proportionate volumes	measured volumes	measured volumes	measured volumes
			wall thickness	wall thickness	wall thickness
					wall stratigraphy
					technological detail
	INFORMATION		function of spaces	function of spaces	function of spaces
				materials	materials
	GRAPHIC CODE				
	R. BASED ON DATA				
	R. BASED ON HYPOTHESES				

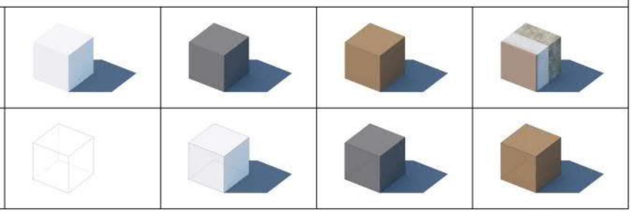


Fig. 7. LOR levels and their graphic codes

Four LORs are identified: A, B, C, D in ascending order, and the LOR chart is related to the type of drawings (Fig. 7). It should be noted that the table is constructed with the attitude of the philologist that does not exceed the level of design definition proposed by the designer. There is a distinction between the part of the model based on data and that based on hypothesis; the differences are displayed through the definition of the graphic codes. In the definition of the codes visualization, it was taken into account that the reading of the hypotheses is easily recognizable for the territorial scale; while, for the detail at the building scale, the recognizability depends on the distance of the observer as reported by the theoretical assumptions of restoration theories. Below is the specific definition of LOR levels: Level A, in which the model is characterized by proportioned volumes and it is shown with monochrome black/white (Fig. 8); Level B, in which the model is characterized by measured volumes and known wall thicknesses, and it is shown with a gray scale or a single shade (polychrome) – the different shades are assigned to homogeneous groups of elements (Figs. 9-10); Level C, in which, in addition to the information of the previous level, the knowledge of the materials is added and is shown through the colors (correspondence) - assigned according to the materials they refer to (Fig. 11); Level D: in which the model is characterized by measured volumes, known wall thicknesses and defined stratigraphic composition and the presence of technological details. This level is visualized with photorealism - in which in addition to the color of the materials there is also their texture (Fig. 12).

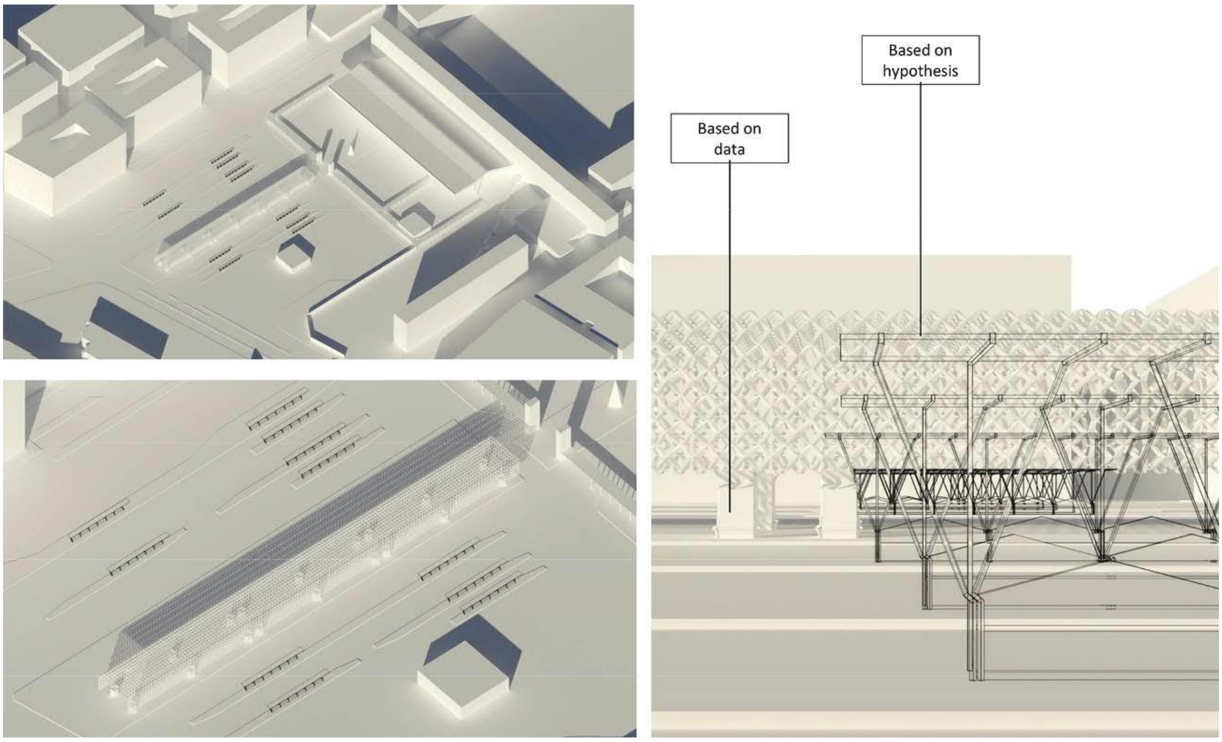


Fig. 8. LOR A: digital transcription of Francesco Cellini project for Piazza dei Cinquecento, Roma

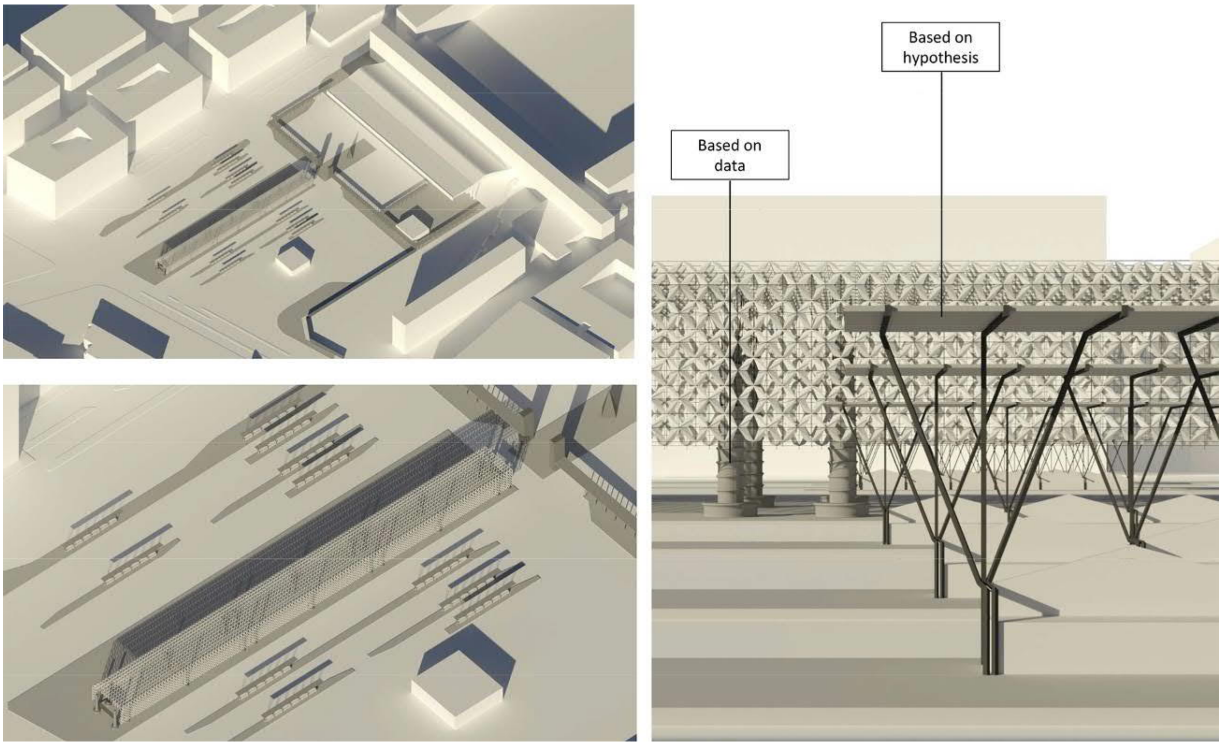


Fig. 9. LOR B: digital transcription of Francesco Cellini project for Piazza dei Cinquecento, Roma

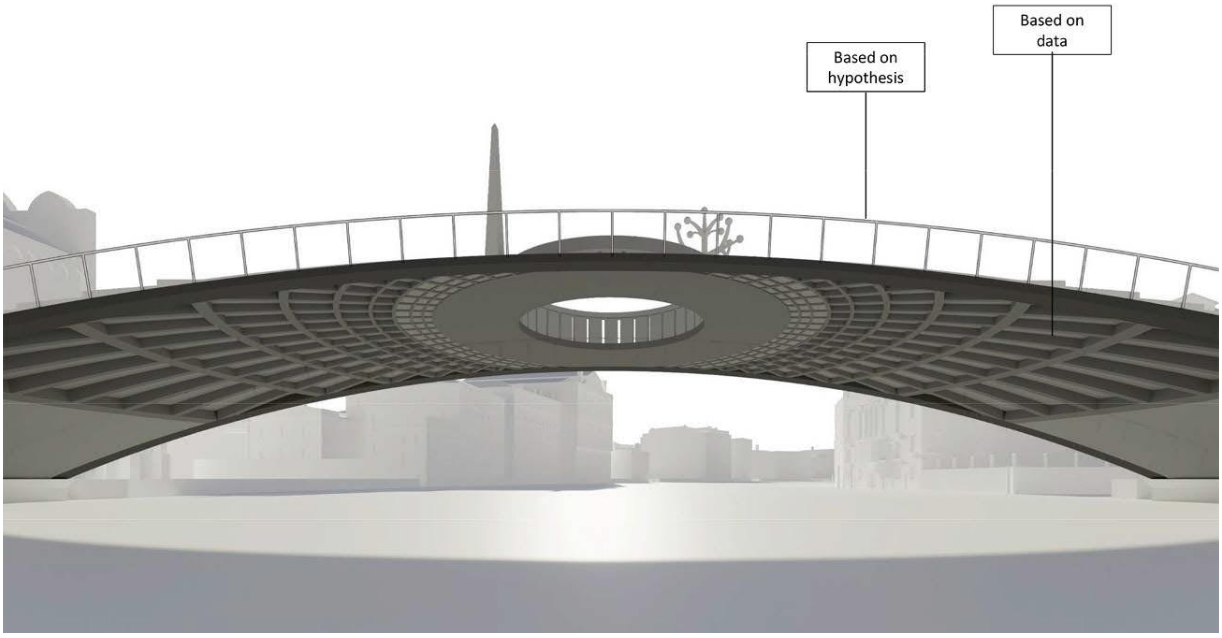


Fig. 10. LOR B: digital transcription of Francesco Cellini project for Ponte dell'Accademia, Venezia

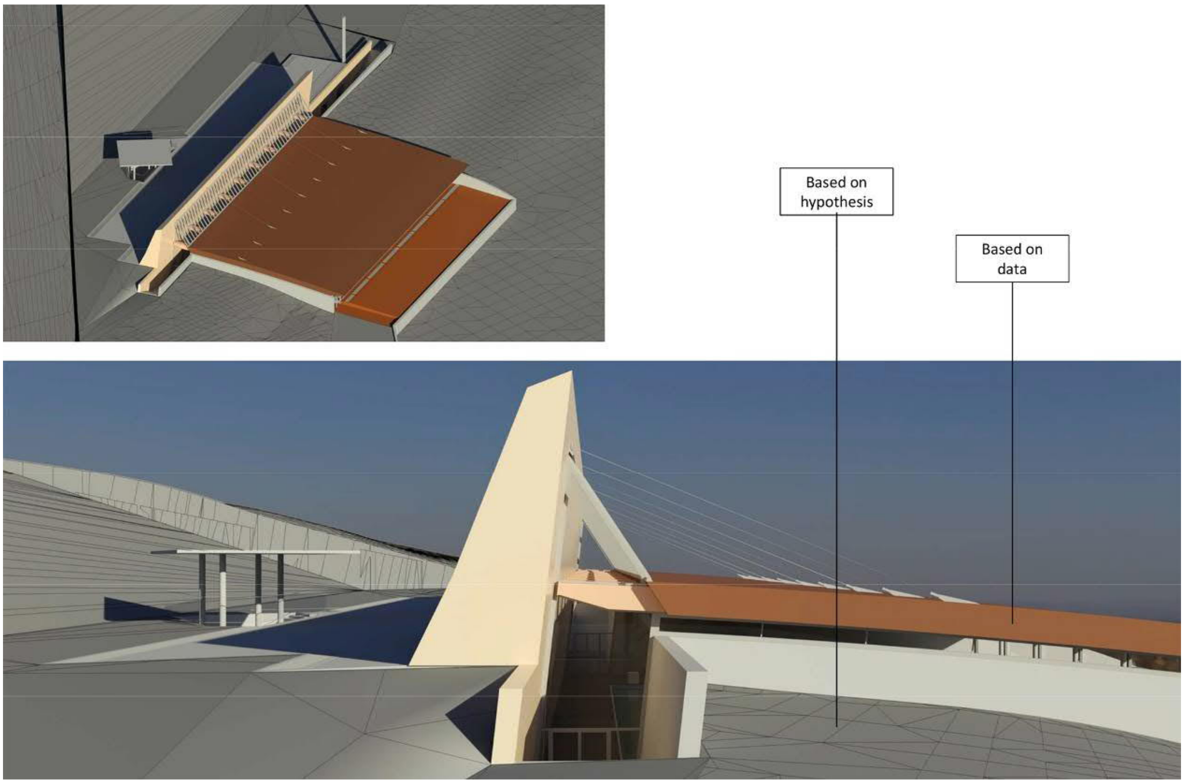


Fig. 11. LOR C: digital transcription of Francesco Cellini project for a pool, Baschi

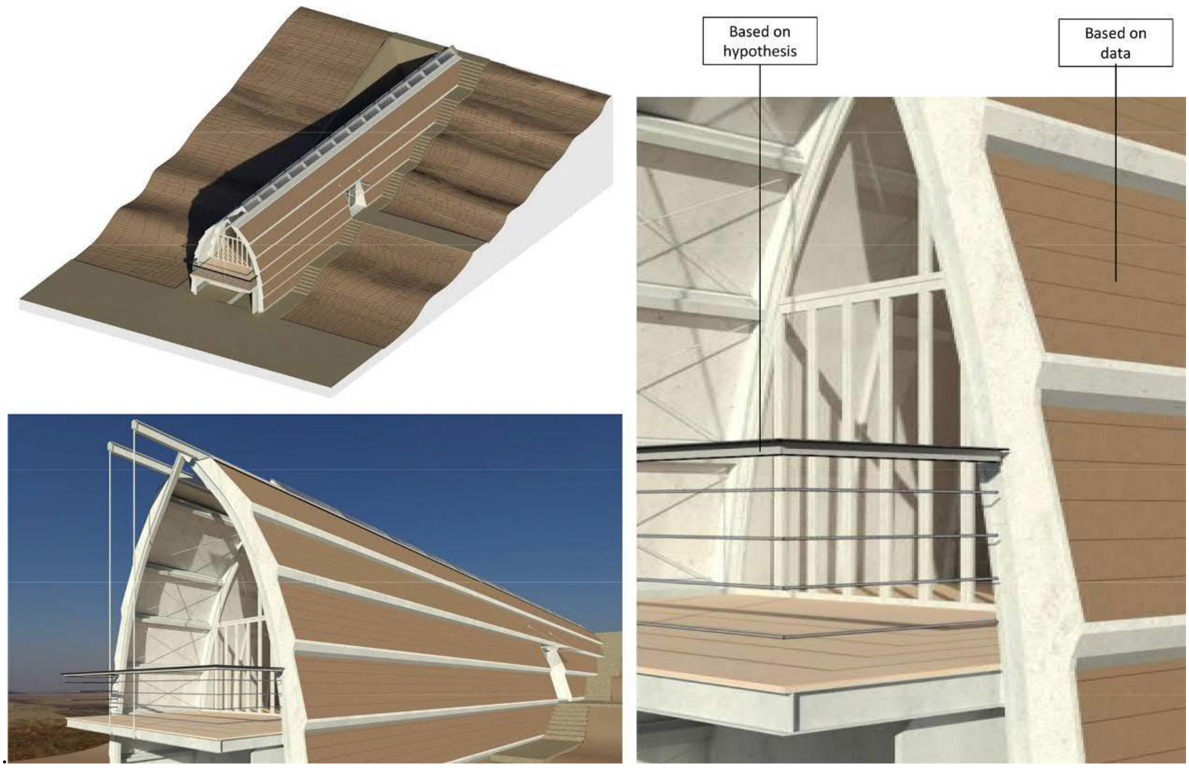


Fig. 12. LOR D: digital transcription of Francesco Cellini project for rowing facility, Baschi

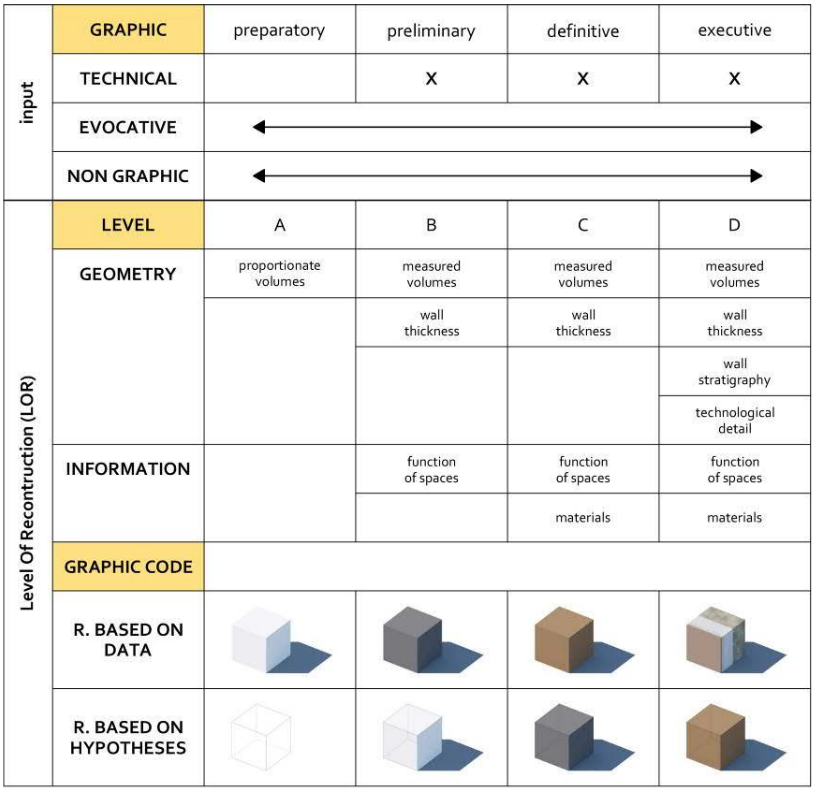


Fig. 13. The chart resumes the whole protocol starting from the archival drawings to the LOR levels definitions

CONCLUSIONS

In conclusion, the proposed chart indicates a protocol for working on a digital transcription process of architectural drawings (Fig. 13) in order to make the 3D modelling process a reliable transcription of the architect's designer intent. The reliability is given by the structure of the model, defined according to the analysis of the original drawings, but also through its visualization where the original and hypothetical data must always be recognizable. In this way it is also possible to check the interpretations both as a choice of technical solutions and as a language. There are many open paths, among these it has been started the semantic structuring of the models [Apollonio 2012] in relation to the belonging LOR. The research also highlighted the need to visualize the graphic style present in non-technical drawings. The definition of the LOR is limited at this moment but effective for the case study. It is intended to widen it according to several cases belonging to different eras: for example by interpreting drawings by renaissance architects where often survey and project coexist in the same drawing. Graphic codes will also have to be expanded as there are many signs that can be detected in analogical drawings that require different reflections in their digital transcription. The authors intend to develop an application capable of concretely managing the modelling through LOR levels.

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Working Experiences with the Reconstruction Argumentation Method (RAM) – Scientific Documentation for Virtual Reconstruction

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Interest in the field of digital heritage has grown considerably over the last couple of decades, giving rise to a wide range of representations that aim to visualize the past. Although the visual results of these efforts are relatively accessible, the knowledge underpinning the majority of these reconstructions is not properly documented and will most likely get lost. It is hard to proceed at a later stage with a further iteration of a reconstruction, as the earlier argumentation and the reasons for the decisions that were taken to arrive at the acquired interpretation are no longer available. In order to bridge this gap and to preserve the accumulated meta-knowledge, a web-based tool – called "*sciedoc*" – was developed in 2017. This paper presents experiences with this documentation environment and outlines considerations towards further developments.

The experience of working with the tool led to the insight that it is not only useful for documentation but also as a communication tool between the academic and technical sides of the team carrying out the reconstruction. Moreover, further, different structures of documentation ("grammar") came to the fore which might be helpful in the future. Lastly, this paper also considers the use of colored models to present an overview of plausibility and used sources in reconstruction.

Key words:
Virtual Reconstructions, Scientific Documentation, Standards, Online Tool, Graphic Evaluation

CHNT Reference:
Marc Grellert et al. 2018. Working Experience with the Reconstruction Argumentation Method (RAM).

INTRODUCTION

This paper seeks to foster systematic documentation practices and, with it, the development of (visual) argumentation standards that will benefit the field of digital heritage. There is a definite need for preserving access to the comprehensive body of information and arguments underpinning any given virtual reconstruction to keep the decision-making process transparent, traceable and comprehensible. In other words, the intermediate steps of interpretation – based on a specific set of material collected in archives and in the field – are accessible and displayed and may thus give rise to alternative variants and interpretations. As the overall process of reconstruction tends to be very time-consuming, it is proposed to establish a "minimum" standard of documentation.

The ongoing development and implementation of a web-based platform – called *sciedoc*[1] – serves as the starting point for the discussion of how it might be possible to incorporate the traces of the underlying argumentation in

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[1] www.sciedoc.org

order to make the preservation and transfer of knowledge through visual means in the field of virtual reconstruction more effective.

This paper presents a further development of the *sciedoc* interface along with experiences of already documented reconstruction projects in this platform. Furthermore, it sums up the outcome of discussions between the involved partners concerning some principal questions related to imaging the past:

- Which intellectual, technical and aesthetic approach should be adopted to ensure the transparency of hypothetical reconstructions processes?
- What should a reasonable categorization of plausibility concerning reconstructions consist of?
- What would be the best way of using the interface as a communication tool during the reconstruction process?
- What would be the appropriate way of presenting the level of plausibility in hypothetical reconstructions, while at the same time presenting the underlying sources? Are graphic overviews helpful and how should they be organized?
- What would be the best way to ensure transparency relating to evidence data, archival documents and conjectural interpretations?

Overall, the experiences with the interrelationship of documentation within the framework of reconstruction are depicted. The context of research-driven teaching and activities is partly narrowed by specific building typologies, destroyed synagogues (sacred buildings).

COMPREHENSIBLE DOCUMENTATION

The application of computer-based visualization in the field of virtual reconstruction is inherently characterized by “highs and lows”. It demonstrates not only the extraordinary potential of digital technologies but also its weaknesses and inconsistencies. This problem was first tackled in 2006, when the “The London Charter for the computer-based visualization of Cultural Heritage” [London Charter 2006] was drawn up, and again in 2011 with the “International Principles of Virtual Archaeology. The Seville Principles” [2011]. Geared towards the needs of research and communication of cultural heritage, the two charters defined guidelines for the use of computer-based visualization in relation to intellectual integrity, reliability, documentation, sustainability and access of heritage artefacts.

Despite some proposals in recent years [Demetrescu et al. 2016; Gonzalez-Perez et al. 2012; Kuroczyński et al. 2016], the scientific community has not yet succeeded in developing and establishing operational standards that would allow, for example, for the expression of the degree of hypothesis in the visualization of the data model, or what the data model behind the 3D visualization looks like, or how the process adopted could be mapped or referenced in the 3D model.

Based on the absence of standards for the scholarly documentation of virtual reconstructions and the lack of such underlying documentations themselves, the goal defined in 2016 was to develop a user-friendly and easily understandable online tool that can be used without any prior knowledge or specific software know-how [Grellert et al. 2018; Pfarr-Harfst and Grellert 2016]. The tool should not only serve most architectural reconstruction projects, it should also be affordable. A further goal was to keep obstacles small. In other words, the interface should not require highly specialized IT or visualization skills. Moreover, the transformation of an existing model into another software environment was ruled out.

Basically, the structure of *sciedoc* consists of a documentation of the sources relevant to the reconstruction along with a (short) written statement (=argument) underpinning the graphic representation of the reconstruction.

In the course of recording the reconstruction process, the outcome (model) is divided into several different *areas*. For each of these *areas* one or more alternative solutions (*variants*) can be documented in order to explain how the model has been set up. This acknowledges a new conceptualization of reconstruction methods that accepts that a single solution cannot be the goal and that allows for lacunae and for thinking in variants.

Each *variant* of the reconstructive hypotheses is represented by a set of images showing the reconstruction and by the related documentary sources. Images and source information are accompanied by the verbal argumentation. This documentation method is called “Reconstruction Argumentation Method” (RAM) and can be displayed on just a single web page.

Depending on the availability, completeness and quality of the archival material, the grade of plausibility of the reconstruction may differ dramatically. To account for the difference in quality of the source material, a rating system was developed with the following scaling:

1) Substantiated
2) Very probable
3) Probable
4) Possible
5) Not probable

COMMUNICATION TOOL

Based on the experience gained from several completed and ongoing projects (for example, the reconstructions of the Gothic cathedral of Paderborn, the Klenow Palace and the Praetorium and Jewish quarter in Cologne), the *sciedoc* platform is very useful as a communication tool. A common experience in other projects was that, for example, during a telephone conversation it was not immediately clear which image was under discussion. In the *sciedoc* tool, each image, each source, each text etc. has its own unique reference (Fig. 1). Using the tool right from the start as a communication tool ultimately made the documentation much quicker and the process of reconstruction more transparent. Another advantage is that all the copyright information for the used sources can be requested in advance. Open Access is a serious challenge for any documentation and can be time-consuming. The advantages of using *sciedoc* as a communication tool were immediately convincing in the day-to-day exchanges between the academics and the people carrying out the reconstruction.

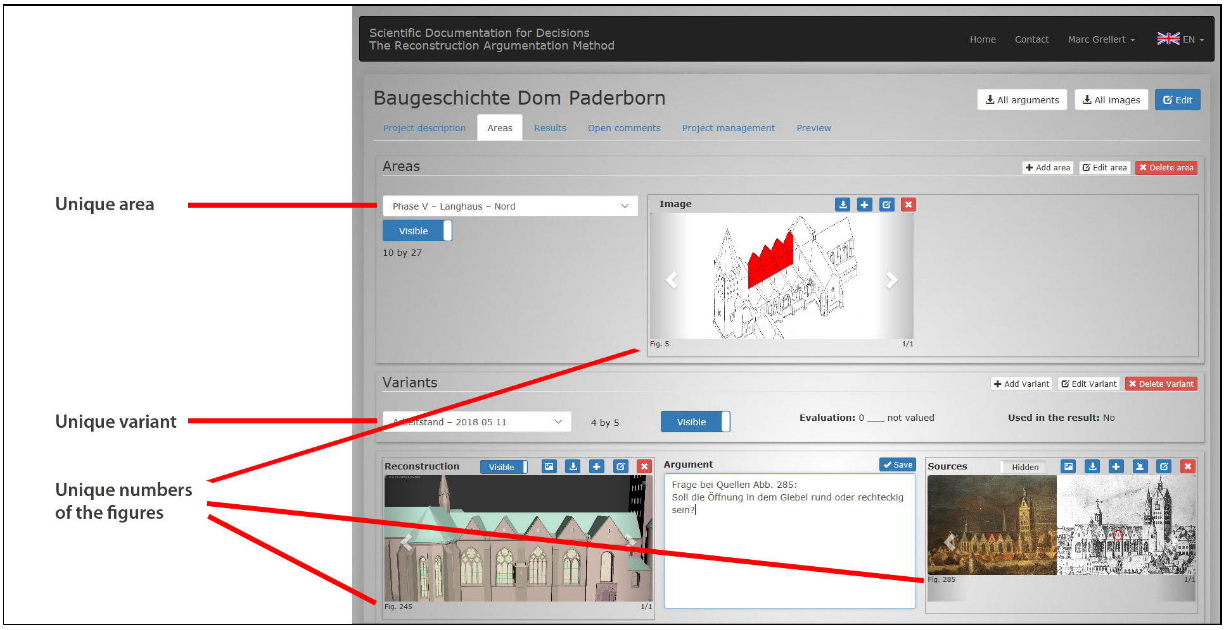

Fig. 1. Screenshot of the sciedoc interface, project Cathedral of Paderborn (© Marc Grellert)

In the reconstruction of the Praetorium in Cologne, a key objective was to bring together a group of about 20 academics to reflect on the ongoing process. As it turned out, even the easily understandable structure of the *sciedoc* tool was too challenging for people looking up the work status just once in a month. An email to this group with images of the reconstruction and the answers to their questions worked better. These answers were then integrated into the platform to make that input traceable online.

STRUCTURE OF DOCUMENTATION

At the time of going to press, 20 projects are online. Four projects are completed and awaiting copyright clearance for the sources. Further 28 projects (17 synagogue reconstructions and 11 other buildings) are currently using *sciedoc*. In terms of date, these projects range from ancient history (11th-century BC Tell Halaf), Roman antiquity (the Praetorium in Cologne) to the middle ages (the monastery at Altenberg) and modern times (St. Johannis, Mainz). It was also extremely helpful to be able to define the structure for the *areas* – the “grammar” in advance. Summing up the experience gained from the various projects, it seems to make sense to allow for a wider range of structural approaches:

- Structured by architectural building types, e.g. churches, palaces, synagogues, basilicas, halls
- Structured by spaces
- Structured by architectural elements
- Structured by specific research questions
- Structured by specific research methods
- Structured by a limited number of sources
- Structured by the new insights

The question is: Once a meaningful structure of documentation for a certain type of building is developed, could this serve as a guide for the structure of the 3D models at the same time? After carrying out quite a number of projects, the authors believe that there will be different useful structures of “grammar” which could act as a pattern for new projects and reconstructions. For the typology of synagogues as a building type – a shared field of research – the universities of Darmstadt and Vienna have developed such a “grammar”.

DESTROYED SYNAGOGUES – EXAMPLES OF DOCUMENTED BUILDINGS

TU Wien has been conducting virtual reconstruction work since 1998 with a particular focus on the virtual reconstruction of destroyed synagogues in Austria and the former crown lands of the Danube monarchy. The principal platform of these efforts is the academic framework of the final thesis (2018: 60+ completed theses). The output does not only consist of written documentations (incl. context, background, etc.), it also encompasses detailed 3D models and visualizations [Martens and Peter 2014]. To facilitate the MA students’ reconstructions, the graduands are linked up with art historians and building history experts who have a vested interest in raising the validity and plausibility of the considerations. The results of the research work are published to reach the widest possible audience.

These buildings, constructed for the most part in the late 19th and early 20th century, follow an overall architectural pattern. As a matter of fact, it is possible to distinguish several useful structures of a kind of “grammar” that can – as suggested above – serve as a typology for future projects and reconstructions. For this reason, the following structure (Table 1) was set up to establish a catalogue of meaningful *areas* (in line with the “grammar”):

Table 1. Principal structure of the areas related to synagogues (19th and 20th century)

Exterior 01 - West façade	Interior 08 - Details – floor
Exterior 02 - North façade	Interior 09 - Details – ceiling
Exterior 03 - East façade	Interior 10 - Details – chandelier
Exterior 04 - South façade	Interior 11 - Details – organ
Exterior 05 - Roof	Interior 12 - Details – pulpit
Exterior 06 - Land borders	Interior 13 - Details – furniture
	Interior 14 - Doors
Interior 01 - East face with ark	Interior 30 - Pillars ground floor
Interior 02 - South face	Interior 31 - Women’s gallery – Pillars upstairs
Interior 03 - West face	Interior 32 - Women’s gallery – balustrade
Interior 04 - North face	Interior 50 - Anteroom
Interior 05 - Details – aron kodesh	Interior 60 - Staircase
Interior 06 - Details –bimah	
Interior 07 - Details – benches	Urban context

This allows to document significant *areas* (Fig. 2) independent of the amount of archival material considered. As the period in question (late 19th century) is roughly a century ago, the probability of finding hitherto unseen archival material is relatively high. A structured documentation also allows for a comparison between the same kind of *areas* in different buildings, for example the “Pillars ground floor” in different synagogues (Fig. 3).

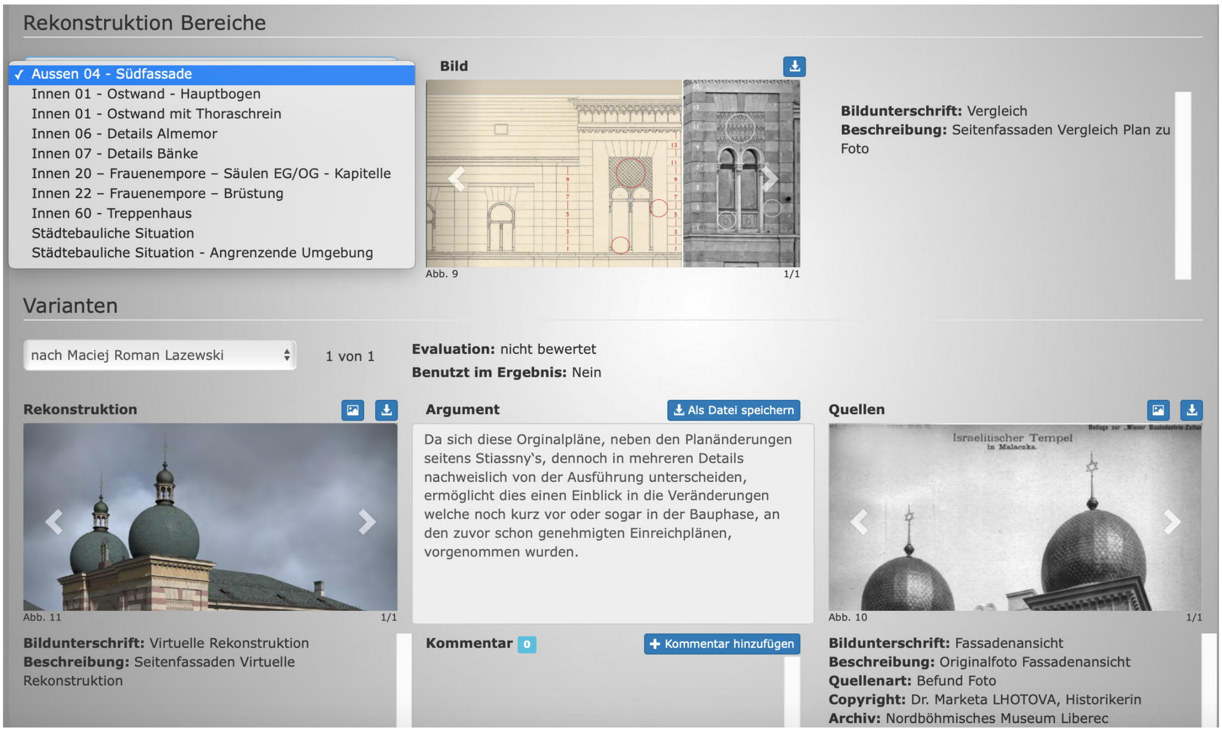

Fig. 2. Screenshot of sciedoc interface, areas of one of the synagogue projects (© Bob Martens)

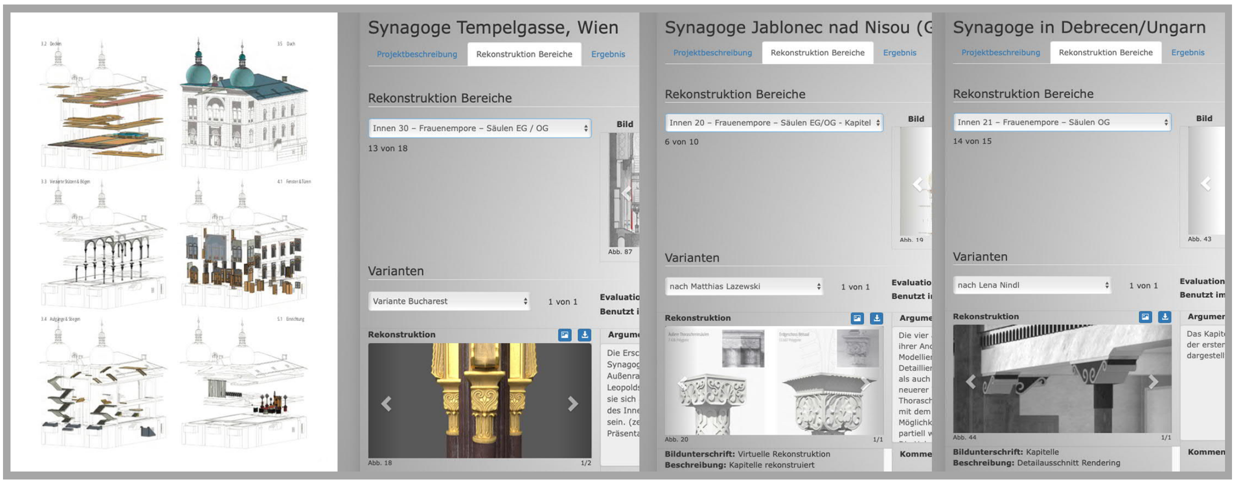

Fig. 3. Left: Structure of the project "Synagogue of Jablonec", right: Screen-shots of the sciedoc interface with the Area "Interior 30 - Pillars ground floor" of different synagogues. (© Bob Martens)

GRAPHIC DOCUMENTATION

In the field of architectural representation, the advances of digital technologies go hand in hand with the development of new tools and methods for 3D data acquisition, documentation and dissemination of information related to architectural-archaeological heritage. This gives rise to a drastic transformation in the way data and information related to any kind of artifact are collected, processed, represented and communicated.

Moreover, the use of virtual reconstruction in archaeology and architecture [Reily 1990] opened the debate, within a multidisciplinary approach, of a wide range of theoretical problems related to documentation [Pfarr 2010], analysis and interpretation of hypothetical reconstruction [Dell'Unto et al. 2013], about the subject of transparency in the reconstruction process [Hermon et al. 2007], and about the definition of new protocols for processing spatial data (acquisition, manipulation and management) [Münster 2013; Grellert and Pfarr-Harfst 2014]. Within this wide context, in order to validate the entire 3D modeling reconstruction process and to facilitate the exchange and reuse of information as well as collaboration between experts in various disciplines, new standards are necessary, due to the reusability and accessibility of knowledge linked to 3D digital models [Apollonio and Giovannini 2015; Apollonio 2016a]. For a better interpretation of a digital heritage artifact, a comprehensive interpretive method is needed. Because many hypothetical reconstructions are the result of a highly complex decision-making process [Kőller et al. 2009], we have to focus attention on the cognitive-reconstructive process and its ability to transfer knowledge and communicate information related to a source-based reconstructive process [Apollonio et al. 2017; Apollonio 2018].

The source-based reconstructive process is a reverse process which starts (a) with the collection of documentary sources or the collection of reality-based data, defines (b) the semantic structure of a case study, interprets (c) its shapes (dimensional, geometric and morphological consistency), and produces (d) a semantically enriched 3D digital model. From its starting point, the data upon which the hypothetical reconstruction model is built, accumulates an unknown, thus unpredictable and unquantifiable, degree of uncertainty and/or reliability [Apollonio 2016b]. Without a degree of confidence, expressed by the uncertainty/reliability of the incorporated data, the final model cannot be critiqued or properly evaluated from a scholarly point of view. The information necessary for completing the hypothetical virtual model is not always obtainable in a single and unambiguous way from data sources or drawings that we have at our disposal. All information collected may be conveyed by using different technologies of visualization, defining a structured modeling process based on different levels of interpretation, characterized by a progressively increasing ordinal scale of uncertainty.

The hypothetical reconstruction process is influenced by various factors, each of which plays its own role and carries its own weight in arriving at the final outcome. Therefore, a structured modeling process is based on different levels of interpretation, characterized by a progressively increasing level of uncertainty: different type of information (deduced or induced) may be conveyed through different solutions, adopting (i) new 3D symbology (e.g. a series of glyphs 3D), (ii) animation techniques display, (iii) rendering techniques and (iv) a combination of text metadata and 3D visualization.

In [Apollonio et al. 2013] a method using color to depict uncertainty was proposed, based on the definition of a structured modeling process and on different levels of interpretation. The degree of uncertainty of a reconstruction is visualized by a sliding pseudo color scale that divides the rendered objects into a few color bands to express the separate level of interpretation/uncertainty.

This first proposal was only able to represent the different levels of uncertainty related to the coherence/pertinence of data sources used. Any hypothetical reconstruction, in fact, is not a black/white or yes/no process, but a more complex and interconnected analysis and interpretation of documentary sources affected and/or characterized by different degrees of (a) coherence/consistency, (b) accuracy/metric quality and (c) subjectivity/perceptiveness. A diagrammatic representation of the inter-reference and interconnection among these three aspects is in Fig. 4, where the single nodes of the mesh represent the different levels of interrelation between coherence, accuracy and subjectivity in the definition of each of the constituting elements of the reconstructed artifact.

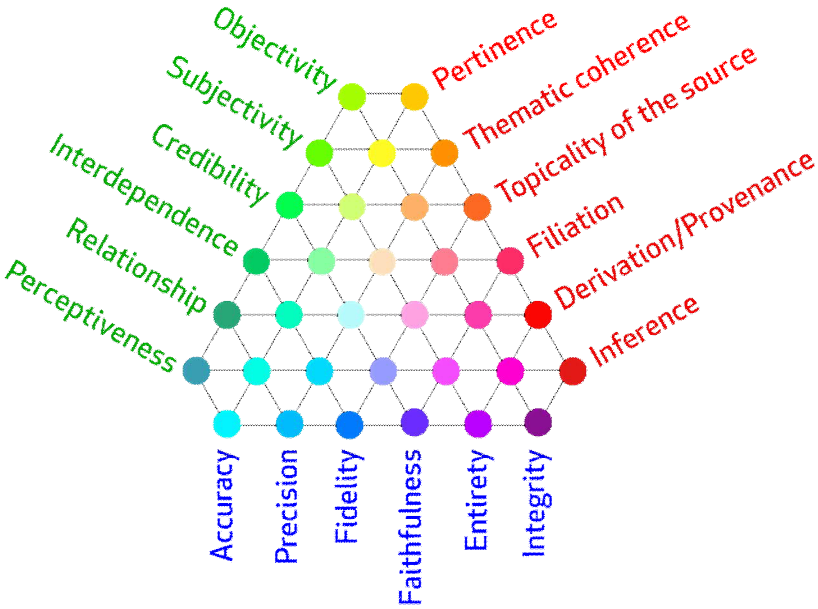

Fig. 4. Diagram representing the interrelation between coherence, accuracy and subjectivity (© Fabrizio Apollonio)

Coherence/consistency could be related to: the reference to contradictory sources; the entirety/integrity of original sources (e.g. a fragment of a document); the consistency of information recorded in sources; filiation, i.e. sources derived from other sources and the relevance or currency of the source. Accuracy/precision/metric quality could be related to: faithfulness/error arising from the device used for the survey (i.e. manual survey vs laser scanner); precision due to different graphic qualities of the source. Objectivity/subjectivity/perceptiveness could be related to: different abilities to interpret the sources; the credibility/reliability of the data source; level of objectivity/subjectivity, i.e. elements conjectured/deduced through knowledge (e.g. conjecture of a capital from an architectural treatise); interdependence/relationship, when we refer to sources based on other sources.

In order to overcome the limitations of previous methods – at least in part – the authors put forward a new proposal that could be developed in relation to subjects on *sciedoc*: the scaling of the plausibility of variants and a categorization of the used sources (Fig. 5). The idea was to give an overview of a reconstruction by presenting two images side by side (Figs. 6, 8).

1. - Rendering of the reconstructed building
   - Same perspective of the building - parts are colored to reflect plausibility
2. - Rendering of the reconstructed building
   - Same perspective of the building - parts are colored to reflect the used sources
3. - Perspective of the building - parts are colored to reflect plausibility
   - Same perspective of the building - parts are colored to reflect the used sources

Working together, the authors developed the already mentioned scaling of the plausibility of the *variants* into "Substantiated", "Very probable", "Probable", "Possible", "Not probable" and, at the same time, a categorization of the used sources. Different types of used sources were defined, but their positions in the listing and in the diagram do not represent any graduation value. They are structured into two hierarchical levels: the first related to the different uses / origins of those documents, the second to the different types of document:

- Building survey
  - Laser scan of architectural remains
  - Building survey drawings
  - Photographs of the building
- Designs
  - Drawings carried out
  - Drawings
  - Maquette
- Interpretations
  - Maquette
  - Contemporary drawings / sketches
  - Reliefs, seals, coins
  - Written and oral descriptions
- Analogies
  - to constructive systems
  - to buildings, ideas, etc.
- Derived from sources used
- Failing references

The two categorizations and the use of colors: The level of plausibility should be just one color with different degrees of saturation. This one color should not be part of the palette used for the sources. The following table shows the proposed color scheme:

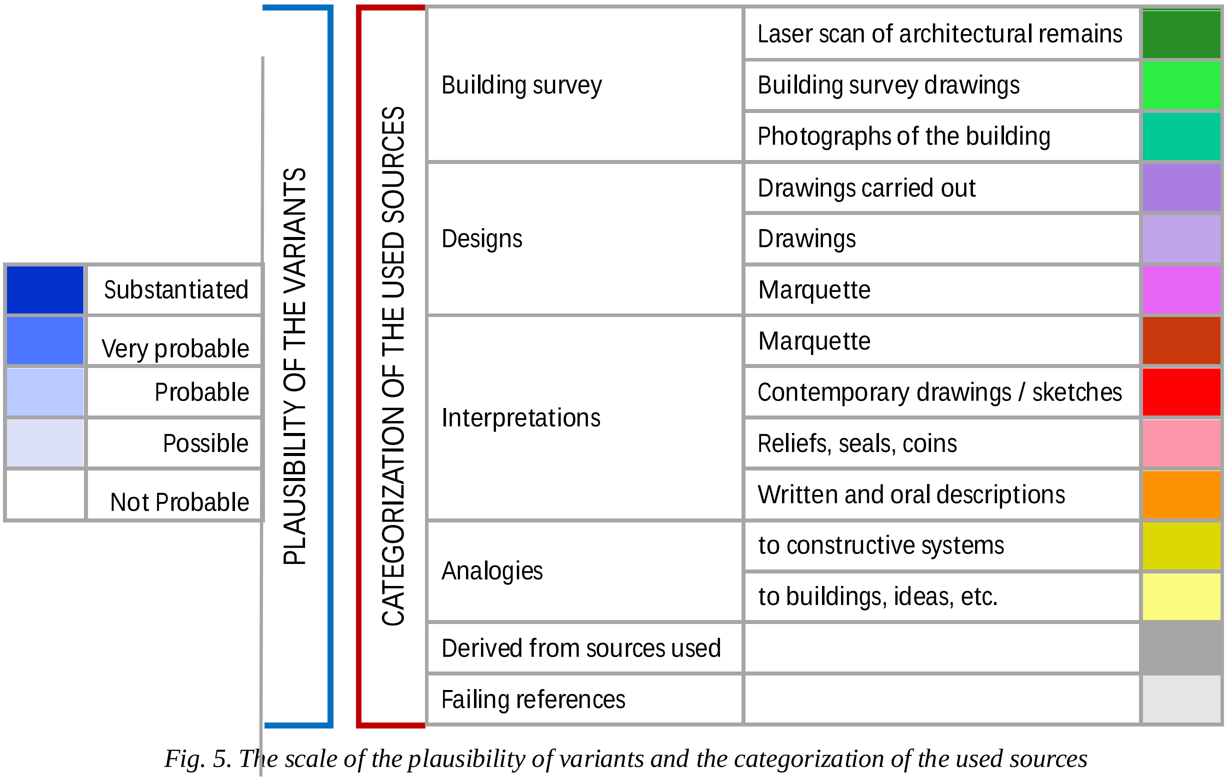

Fig. 5. The scale of the plausibility of variants and the categorization of the used sources

The proposed method was applied to some case studies. The first is the Church of Santa Margherita (Bologna, 1736). The design by V. Barelli shows the hypothetical reconstruction of the external church of the Benedictine cloistered monastery of Santa Margherita in the period between the end of the 16th century and the middle of the next. During that period, the church, which no longer exists, was the subject of a series of renovation and/or reconstruction projects [Costarelli 2015; Caprara 2002], documented by various drawings, plans and some sections, none of them are dated and not all of them easy to attribute to a specific author or to fit into a chronological sequence (Figs. 6 and 7). The second is the western cloister of the Cistercian monastery in Altenberg, founded in 1183 and fallen into ruin at the beginning of the 19th century. The reconstruction concerned the configuration of the monastery in the period between 1200 and 1400 AD (Fig. 8).

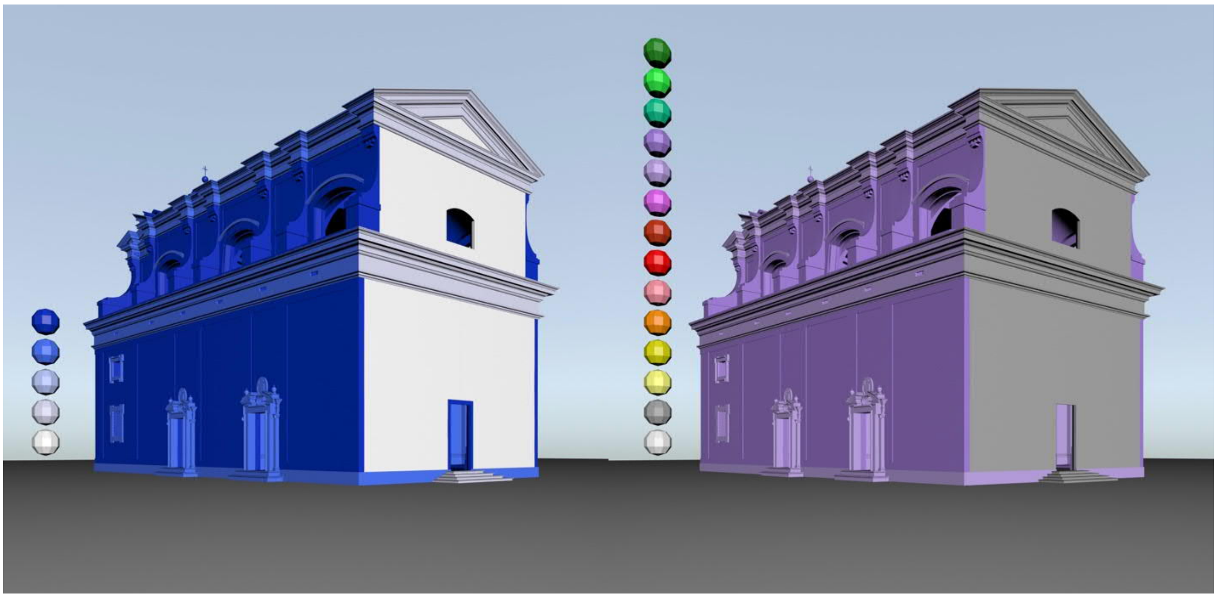

Fig. 6. Santa Margherita (exterior): representation of the scale of plausibility (l.) of variants and the categorization of the used sources (r.) of the hypothetical reconstruction based on V. Barelli's design (© Fabrizio Apollonio)

Fig. 7. Santa Margherita (interior): used sources of the hypothetical reconstruction based on V. Barelli's design (© Fabrizio Apollonio)

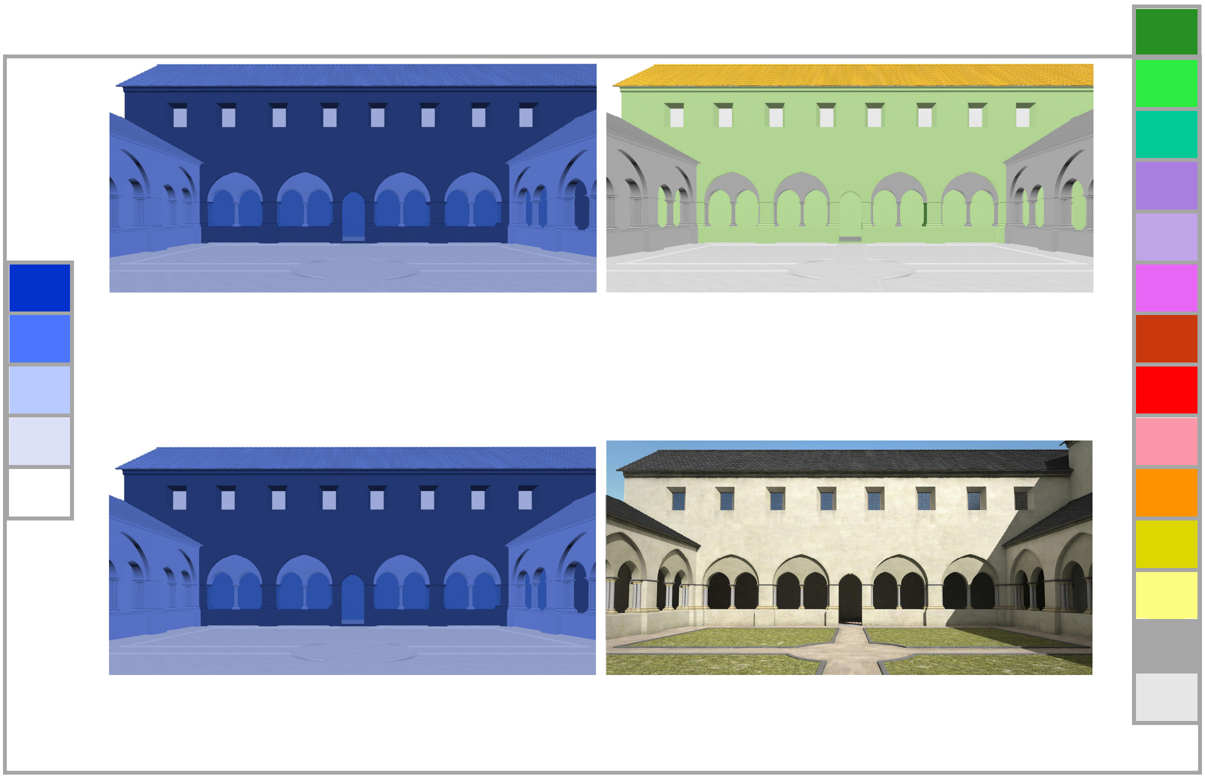

Fig. 8. Monastery of Altenberg, western cloister. The reconstruction was carried out for an exhibition at the Rheinisches LandesMuseum Bonn and shows the monastery as it might have looked from about 1200 to 1400 AD. Above: level of plausibility and used sources, bottom: level of plausibility and rendering (© Marc Grellert, Norbert Nußbaum)

CONCLUSIONS AND OUTLOOK

This paper outlines the need for scholarly documentation in the field of digital heritage. Ongoing developments with the online tool *sciedoc* have been described and its practical handling demonstrated. Its use as a communication tool is very convincing in the day-to-day work between the academic and the technical sides of the teams involved in the reconstruction.

When entering a reconstruction project into *sciedoc*, the pre-structuring of *areas* (interior/exterior) is of importance to speed up the data entry and in future hopefully also for structuring the reconstruction itself. Although the current interface is to a certain degree self-explanatory, tutorials and guidance would be useful. Now that the number of recorded projects in *sciedoc* is growing steadily, a comparative analysis of the different decision-making processes involved has proven beneficial. Data entry at the TU Wien currently tends to take place after completion of the thesis work. However, in the future, this is expected to happen at an earlier stage in order to enrich the level of discussion and interpretation.

Further implementation could concern, for instance, the use of graphic visualization of the level of plausibility as proposed above. If we assume that each constituent *area*/element of a model is characterized by its own level of plausibility (ranging from Substantiated = 1 to Not probable = 0), the results of modeling processes can be represented by a unit vector described by a set of components that add up to the given vector. Each vector representing the plausibility value of each *area* is graphically defined in Cartesian space by a line segment connecting the initial point (0.0) with the terminal point which could range from (1.1) to (1.0). The overall plausibility value of the reconstructed model as a whole is represented by the sum of each unit vector representing each *area*. The process of creating a hypothetical reconstruction, in fact, may be modeled as a "construction" set of parts that need to be assembled in order to generate the final complete model. It is an incremental process in which one starts from an initial model *M0*, placed at position *x0*, adding the model of a new element.

At step *n* a new model *Mn+1* is built from *Mn* adding a new detail *mn + 1* in an absolute position *xn + 1*. The *n* unit vectors represent the plausibility of each *n* element hypothetically reconstructed. The plausibility of the *area X*, composed by *n* elements, is represented by the summation of each new detail added with its own value of plausibility. And, similarly, the plausibility of the final model *M* - composed of *n areas* - may be computed (step by step) as the summation of each *area* added with its own value of plausibility (Fig. 9).

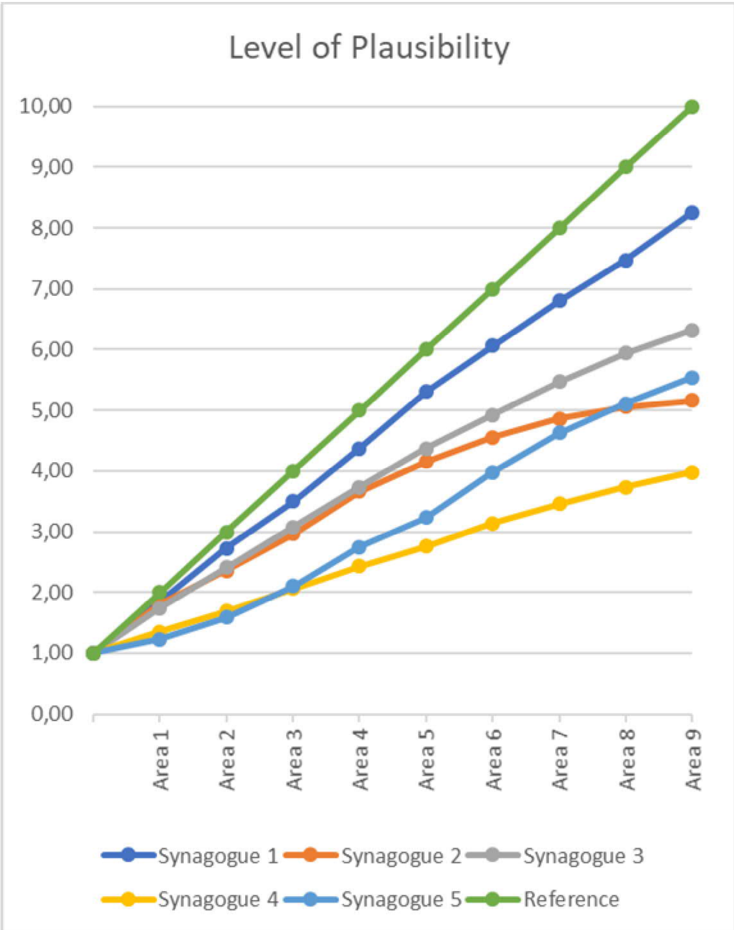

Fig. 9. Example of diagram representing different levels of plausibility of different reconstructive hypotheses concerning five synagogues composed of nine areas (© F. Apollonio, M. Grellert, B, Martens, N. Nußbaum)

At this stage, an evaluation of user behavior regarding the interaction with the interface does not seem feasible. However, this needs to be considered for future work by way of structured interviews and/or questionnaires. Overall, this is scheduled in the framework of a recently submitted research grant application.

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Interactive Virtual Reality for a Grasping Understanding of an Architectonic Concept

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During the Counterreformation In the early seventeenth century, the archbishop of Würzburg, Julius Echter von Mespelbrunn, 1545–1617, built and transformed several hundred mostly village churches that seem to follow a common principle that by itself has never been realised due to the varying preconditions. Prof. Dr. Barbara Schock-Werner, architect, art historian and former master builder of Cologne Cathedral, verbally described this hypothetical ideal church in her habilitation treatise. The research problem was to find a way to translate this very concrete verbal description into an adequate visual representation. Its aim was to substitute the verbal hypothesis by its visual counterpart. The project demonstrated in this paper describes not only how the ideal church has been translated from the verbal into a virtually modelled form, but also how it has been mediated to the public by an interactive Virtual Reality experience introduced by a narrative film and a physical model of the ideal church. The Virtual Reality experience includes four phases. In the first phase the operator learns how to compose typical Echter churches from a given set of building parts of nine churches, i.e. eight existing plus the ideal church. He composes by identifying, selecting and arranging the parts in their appropriate orientation. As he operates in the virtual space, he handles virtual representations of his hands by special controllers. The objects themselves are represented in the scale one to one hundred, i. e. in a common model scale that inspires a manual interaction. And as the also seem to behave physically correct, handling and behaviour encourage the operator to experiment. When the operator successfully composes a church's volume, his visual presentation switches to an original scale representation that allows walking around the churches. The ideal church can also be visited from the inside. It is one of the specific strengths of Virtual Reality not only to simulate space and interact with it but to deliberately switch between different states, e. g. scales, levels of details or levels of abstraction. The benefit is the shift from realism to abstraction, just as in any other media like images or texts. Abstraction in any way or media allows to demonstrate, explain, illustrate and in the end understand concepts directly which otherwise can only be perceived subtly.

Key words:
Architecture, Visualisation, Design, Abstraction, Uncertainty.

CHNT Reference:
Lengyel and Toulouse. 2018. Interactive Virtual Reality for a Grasping Understanding of an Architectonic Concept.

CULTURAL HERITAGE AND HISTORICAL SETTING

Julius Echter von Mespelbrunn built about four hundred churches in the position of the prince-archbishop of Würzburg during the counterreformation in the early seventeenth century. Among others, one of his intentions was to demonstrate the superiority of Catholicism over Protestantism which fully succeeded according to chronists.

For this vast project that he undertook amongst many other building projects, first of all he manifested his responsibility for form and design of all building projects within his bishopric. This general responsibility led to a certain and most probably intentional homogeneity in the exterior and interior appearance of the churches. Some of the churches were built on existing sites or even on parts of existing churches. For example, in a number of cases he took over and integrated the church towers.

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Fig. 1. Julius Echter's ideal church with school and parish house in a paradigmatic village context [Lengyel and Toulouse 2017a,b] © Lengyel Toulouse Architekten

In general, his new or transformed churches resemble each other to a rather high degree. On the outside their basic formal design components, that is nave, choir, vestry and tower, are assembled in a highly conformable way. Just as well in the inside vaults, altar, pulpit and baptismal font follow common design rules. Even the overall colouring design of walls and decoration is mostly uniform or very similar. It seems obvious that there must have been a clear vision, a primordial idea of the churches before they have been built.

BUILDING RESEARCH AND HYPOTHESES

This vision has hypothetically been formulated by Prof. Dr. Barbara Schock-Werner, the former master builder of Cologne Cathedral [Barbara Schock-Werner 2017]. The historic ideal has not survived, if there has ever been a formal description at all, so it had to be reconstructed indirectly. The verbal hypothesis describes every single feature of an ideal church from the outside to the inside as if it was built in a detailed way. The reader can imagine visiting the ideal church and is strongly reminded of existing churches. The structure of this description is not a generalization in the form of a strong formal abstraction as executed for example in the case of the urban texture of the antic metropole of Pergamon (Fig. 2) or the urban texture around Cologne Cathedral (Fig. 3) in times when as little is known about the single buildings that a rough and obvious geometric abstraction clearly explains this uncertainty in archaeological knowledge [Lengyel and Toulouse 2016]. In the case of Echter's churches the idealisation is realised as a series of descriptions of rather subtly idealized single features of existing churches, an assemblage of the most common and most typical single components, a combination of existing parts that in reality have not been built as part of one single church. This also comprises the standard surrounding buildings school and parish houses (Fig. 1). The term 'idealisation' is meant as the most probable original form and appearance of the church as conceived by Julius Echter. Still, the ideal church is not a simple arrangement of existing parts as these contain obviously unintended irregularities and have undergone deterioration and sometimes even restauration, which gives them a unique and singular shape. On the contrary, describing their respective ideas means to imagine and describe their original and intended shape which necessarily is more abstract than their today's remaining descendents.

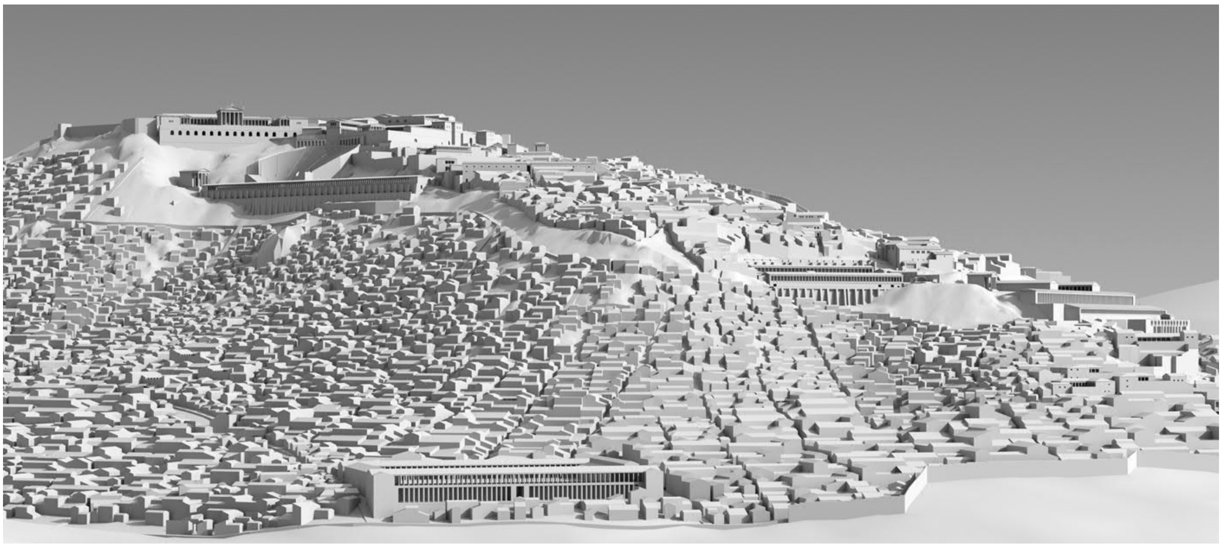

Fig. 2. Antic metropole of Pergamon at around 200 AD [Lengyel and Toulouse 2018] © Lengyel and Toulouse, University of Cottbus

ABSTRACTION AND VISUALISATION

Based on these prerequisites and on occasion of the envisaged exhibition on Echter's cultural impact on his era, which included architecture only among other fields, the idea arose to visualize this idea of a church that would become the origin of several hundred instances, so to create a visual counterpart to the existing verbal description.

The result is a translation into a three dimensional composition mediated in still images, moving image and in Virtual Reality. A geometric translation of a verbal scientific hypothesis means an original architectonic design. This is an important step since the ideal church's visualisation does not fully rely on existing features. This design includes and combines visible and invisible features. Visible are the features adopted and idealised from several realised churches, invisible is their commonality, their conformity as a result of the examination of several hundred individual churches. That is, the translation of the hypothesis from a verbal to a visual form is to create completely new objects, new pieces of abstract geometry that obviously resemble to a high degree of architecture in its appropriate historic context. But the design process also concerns the difference between realised architecture and an appropriate degree of abstraction, not only to illustrate the churches' own hypothetical design ideas, but also to clearly demonstrate that the ideal church is virtual architecture, an idea as a design origin and not a realised building. The challenge in this approach is to achieve an appearance that credibly represents a supposed design thinking of Julius Echter and that also recreates Echter's idea of architecture in the imagination of the viewer of the visualisation (Fig. 4).

Most supposedly Echter's concept is restricted on those elements of architectonic design that directly control the building construction, technical issues and visual and economic concerns, that is the regulation of the overall form and the proportion of the major building elements, the number of tower floors, window axes and entrances, the colouring of internal and external walls, the construction of the vaults and the overall composition of the interior decoration. He might most probably have invested less effort concerning minor deviations due to local building techniques or less experienced craftsmen. This is why Echter's ideal church does in principle not include the ubiquitous defects of his realised churches but instead their genuine, accurate and idealized appearance. In the same sense any of the usual changes that the realised churches underwent, deformations during or after their construction, destruction, conversions or refurbishments, are not considered. This also helps to let the visualisation clearly appear as a visualisation of hypotheses and not as a simulation of built architecture. On the contrary, and this is the main purpose of a visualisation as such, an idea is supposed to be perceived as an idea. All by itself the visualisation pursues to be identified as an idea and to create an awareness of the concept that Julius Echter might have most probably had in his mind [Deuring 2016]

Fig. 3. Alter Dom, the predecessor of Cologne Cathedral [Lengyel and Toulouse 2011; 2013] © Lengyel Toulouse Architekten

Modelling this new geometry means does not mean to simplify, as one could expect when taking the term abstraction literally, but to recreate its formal shape in weighing and considering its overall visual appearance. While dividing a building into semantic sections like nave, choir and tower, the subdivisions that need to take place within each single section is more complex. As one of the simplest examples in the case of the Ideal Church, the interior surface between the windows is recreated absolutely flat and perpendicular to ground and façade planes. The three steps weighing of edges, the rectification of angles and the modularisation of measure constitute the major part of the design of abstraction.

Perception and examination of these visualisations are intended to engage with Echter's architectural vision, but also to appreciate the quality of his overall architectonic contribution. This also leads to a deeper understanding of any of the individual built churches when visited after the perception and understanding of the ideal church. As nearly all churches have some of the features of the ideal church, the differences between any particular built church and the ideal church is noticed more clearly and may even lead to a deeper understanding of the conditions and prerequisites of the particular building's site and community. All together the mediation of the ideal church as a hypothesis as such and the ideal church's hypothetical appearance in particular strengthen the identification of the local community with their local church and also with the bishopric in total.

MEDIATION IN AN EXHIBITION

In the exhibition, three different ways of representation complemented each other, each performing on a different level of perception to fulfil a most complete understanding of the three-dimensional design idea. Three-dimensional space perception in reality depends mainly on stereoscopy, that is two different projections, one for each eye. This stereoscopic projection has been accomplished by virtual reality glasses but also by an autostereoscopic screen, that carries a foil of small prisms that separate the visibility of the two integrated projection for each eye for a certain, adjustable distance for nine possible positions in front of the screen, and that presents a film with speaker text that explains Julius Echter's architecture. As these still images are composed architectural views we call them "virtual photography" as we treat the virtual model as if it was real and construct the view [Rosa 1994] it as if we were using a real physical camera on the search for perspectives that explain the buildings' characteristics as directly as

Fig. 4. Julius Echter's ideal church [Lengyel and Toulouse 2017a; b] © Lengyel Toulouse Architekten

possible. Real three-dimensional perception is made possible via a three-dimensional print of the ideal church. Not comparable to original scale at all, at least the print is half a meter tall (Fig. 5).

The 3D print serves as an overview over the spatial relations of the building parts. As is does not show any materiality, it stands in the tradition of classical architectural clay models. The unobstructed view with the eyes without VR glasses let the viewer examine the plasticity of the surfaces in the most intensive way. This is why any relief has to be considered carefully. Again, this is a matter of weighing essential against existing but irrelevant features. The roof tiling for example seems not to follow certain rules as far as the verbal description of the ideal church revealed. In order to emphasize the described features we agreed in not to show the single tiles, so that other more important features like the cornerstones get the visual presence that they have on the built churches, too. This example clearly shows how different media demand different approaches and clearly a different modelling. The cornerstones' plasticity is exaggerated while the roof tiles are omitted. The clay model method underlines visual features with plasticity even if in case of the built churches the same features are nearly co-planar cornerstones or distinct pieces of roof tiles.

In its plasticity and direct visual accessibility without any technical means the physical model serves as a spatial introduction conditioning the visitor for the church's architectural shape. The visitor is visually and mentally prepared for the uncomfortable VR experience and can overcome the technical challenges more easily.

The virtual reality projection finally is not only at original scale but it also is interactive, so the viewer can grasp certain objects and manipulate them in several ways concerning their position in space or their visual appearance in order to try different alternatives. This approach allows experimenting playfully with the churches' design and by this experience understands it. For the museum visitor, technological fascination seduces to a more intensive awareness of the topic and therefore to a deeper understanding of the mechanisms of architectural design.

INTERACTIVITY AND UNDERSTANDING

The user is allowed to freely combine the building's components and functions. Compositions created by the user will be compared with Echter's ideal church and with eight realised churches. The task after free experimenting is to reconstruct one of the eight selected churches or the ideal church respectively. Visual feedback supports the user in accurate positioning (Fig. 6). While experimenting, on the other hand, there is a nearly infinite number of possible combinations. Experimenting in a technologically advanced way with Echter's design components allows the visitor of the exhibition to overcome the general distance between exhibits and visitors that also arises from the temporal distance over five centuries.

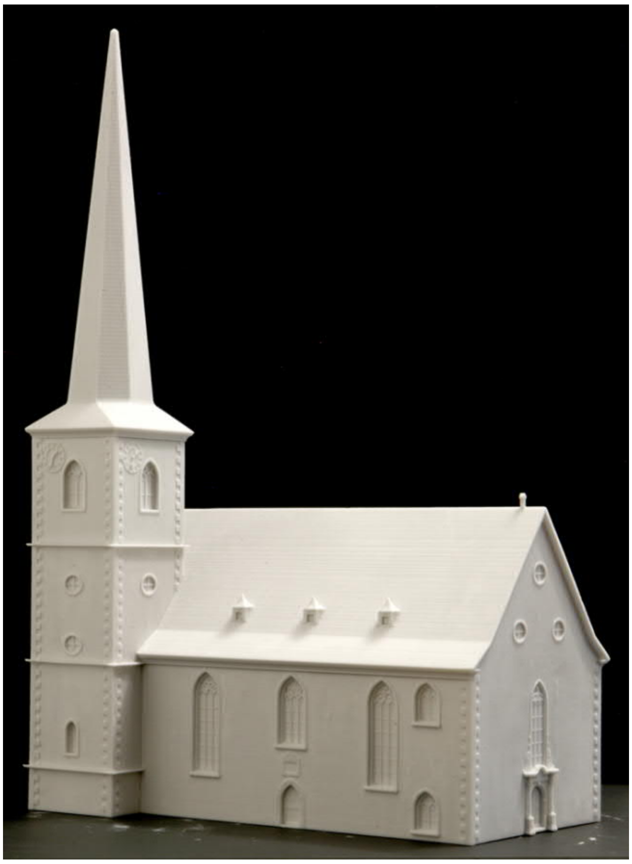

Fig. 5. 3D print of Julius Echter's ideal church [Lengyel and Toulouse 2017a; b]
© Lengyel Toulouse Architekten

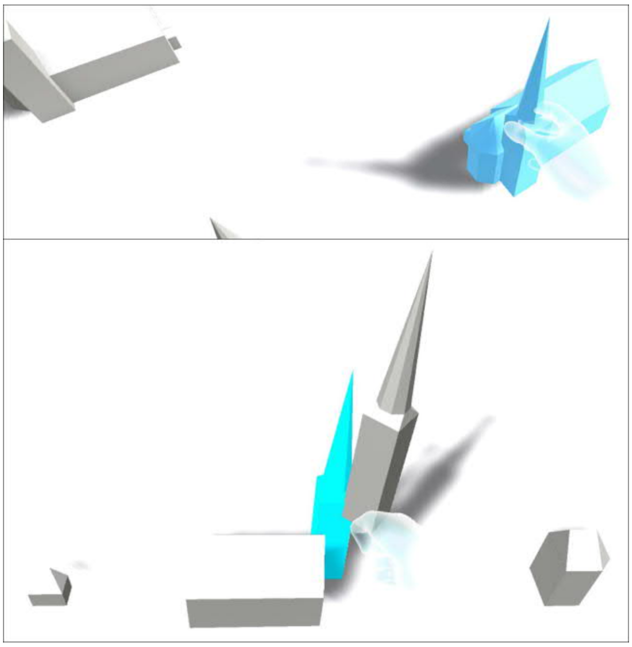

Fig. 6. Interactive optical user guidance, screen shot from Virtual Reality [Lengyel and Toulouse 2017a; b]
© Lengyel Toulouse Architekten

Fig. 7. The gallery of Julius Echter's ideal church [Lengyel and Toulouse 2017a; b] © Lengyel Toulouse Architekten

In the first phase of the interaction the user gets to know the eight realised churches and the ideal church and is asked to select one of those in order to recompose the selection in the second phase from a given set of building parts, that is nave, choir, vestry and tower by identifying, selecting. The composition is performed be arranging and orienting these parts with special controllers that represent the user's hands. The objects in these two first phases of the interaction are represented in the common and comfortable model scale 1:100. This suggests to the user an easy handling of the building parts' abstract representations on his virtual work desk, supported by a physically correct behaviour. That is, if the user reopens his hands, the building hold in the hands falls back down to the ground. The only non-realistic addition to the physical behaviour is an automatic upturn back to the building parts' initial orientation, so that architecture not only metaphorically but literally stands on the ground instead of lying on it. The physical simulation of the parts' handling and behaviour encourages the user to freely experiment with their position.

The objects' weight is adjusted to the impression of light cardboard models to encourage experimenting without having to be afraid of accidentally damaging something. The building parts in this phase are represented in the most abstract respective way. This ensures that the user does not reflect a realised church in its whole appearance but its general spatial constitution. The user learns to think architecturally that is in abstract shapes that represent ideas rather than stones stacked onto each other. Dealing with ideas instead of construction material focuses on the core meaning of the treated object [Pierce 1986]. When the user changes from experimenting to reconstructing and successfully composes a predefined church's set, he is forwarded to the third phase of the interaction that is another model state as original scale model. In this original scale phase the user can walk around the churches. In the case of the ideal church, the user can also walk into the inside of the church (Fig. 7).

The virtual portals are touch sensitive and the user can pass over from outside to inside and vice versa. Other than in scale 1:100, in this original scale physical change of the building parts' position and orientation would contradict the expected architecture's behaviour and irritate the user's imagination of walking around in built architecture. But this does not concern visual features. The colouring of some elements of Echter's colour concept is therefore editable in original scale. As most of Echter's four hundred churches had mouldings and edges in either yellowish or reddish colour, this feature is interchangeable by pointing and clicking on the according surfaces. Also the windows' traceries, one of the most characteristic and famous features of Echters' churches, are changeable. But other than the colouring, and because almost every window tracery in Echter's churches is individual, even if they resemble each other to a certain degree and can be sorted in well distinguishable groups, each window provides five pre-defined alternative traceries in a cyclic order. This allows including diversity as a key feature of Echter's design rules in one single ideal church. Versatility as a design method can therefore be experienced through interaction with the virtual environment.

Fig. 8. The parish church St. Peter and Paul in Schönau. (Photography: Lengyel Toulouse Architekten)

And at the same time the counterpart of versatility, that is consistency, ensures the unity of all churches, the uniformity of the whole as opposition to the versatility of its parts. On the other hand, the variations in the tower helmets have been considered as neglectable. Except two different ways of laying the roof tiles, nearly all tower helmets follow the same overall principle in shape, an iconographic feature for identifying a church by Julius Echter (Fig. 8). This is how architectonic design develops a series of decisions that are directly related to the intended mediation and understanding of the given architecture.

As the section about Echter's churches was part of a major exhibition about his overall tangible cultural heritage, all visitors were necessarily exposed to the 3D print and the autostereoscopic display. The VR glasses were naturally used by only a fraction of the visitors that were motivated for accessing an uncomfortable technical device like VR glasses. To compensate for that, members of the museum staff have been instructed for assisting and evaluating the VR experience. Although the exhibition was visited primarily by visitors that were particularly interested in Echter's heritage and, as Würzburg is situated in the geographical centre of the area of Echter's churches, most visitors would know at least a number of them, the result fulfilled the expectations, that is, visitors having experienced the VR church reported a conviction of deeper understanding of Echter's architectonic concept. Although not being under laboratory conditions, the reports of the members of the museum gave an interesting insight into the acceptance on one hand and effects on the other hand of the VR experience as a supplement to other media.

Fig. 9. The gallery of Julius Echter's ideal church © Lengyel Toulouse Architekten

CONCLUSION

The user experiences architecture and understands basic principles of architectonic design and visualisation, e. g. that different scales demand a different refinement and consequently different modes of mediation, interaction and manipulation. It is one of the specific strengths of Virtual Reality not only to simulate space and interact with it, but to deliberately switch between different states. These states can be scales as realised at the transition from compositing to promenading, that is the transition from the second to the third phase in the project described above, but this can also be levels of details or, most important, levels of abstraction. At our interactive experience of Echter's churches all these features are combined when the user enters the third phase, the interactive promenade. Particularly abstraction, if carefully designed, allows to demonstrate, explain, illustrate and understand concepts that otherwise would be perceived only subtly [Lengyel and Toulouse 2016]. Virtual Reality setups turn out to be a development that allows a deeper understanding of architecture especially in the case of lost or hypothetic architecture. This relies not only on the more spatial experience, that is more explicit than flat projections and not even only on the interactive moving through space, which already enhances the spatial experience substantially. It strongly profits from – and maybe even relies on – the real interaction that is made possible almost exclusively by Virtual Reality, the near to real grasping of objects combined with touch sensitive surfaces that react in a predefined way or cause other elements to perform predefined actions, altogether a combination of different perceptions and the experience of effective intervention. Interactive Virtual Reality will most probably enhance and simplify the mediation of cultural heritage – if performed accordingly (Fig. 9).

The project has been realised for the exhibition "Julius Echter. Patron der Künste. Konturen eines Fürsten und Bischofs der Renaissance" in close cooperation with the former building master of Cologne Cathedral, Prof. Dr. Barbara Schock-Werner. It was funded by the Cultural Foundation of the German Federal States (Kulturstiftung der Länder) and the Bavarian Savings Bank Foundation (Bayerische Sparkassenstiftung) and first exhibited in the University of Würzburg's Martin von Wagner Museum in the Würzburg Residence from June 25 to September 24, 2017. The interactive Virtual Reality experience and the autostereoscopic film presentation have been on a touring exhibition in several villages that possess churches by Julius Echter. From 2018 the 3D model has been part of the permanent collection of the Museum – and from 2019 a new subtitled version of the narrative explanatory film.

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Developing and Maintaining of the Long-term 3D Visualization Projects Caričin Grad – Justiniana Prima

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For more than two decades software for multimedia allows experts of various fields to dive into re-creation of the disappeared historical places and various monuments of the past. The quality of work has been in all times thoroughly scrutinized by the audience, especially by the scientific community which is righteously sensitive about everything regarding approach to the work, elaboration according to the scientifically data at disposal and finally result from which an proper perception of the monument depends. In that way there is no hiding place for the expert(s) whose knowledge and skills are exposed in 3D Restitution of the architecture, either as an individual edifice or as an urban agglomeration. The question of acceptable quantity of "intelligent assumption" and percentage of "hypothetical ideas" will remain omnipresent, meaning that it could not be generalized by numbers but rather reconsidered from project to project, from one monument to another.

The experiences gathered in five successive projects conceptualized as 3D architectural studies for the late-antique city of Caričin Grad –Justiniana Prima in Serbia and achieved from 2002 to 2018 within the Institute of Archaeology in Belgrade, have embodied several premises that could serve well or at least contribute as a guidance in further development of digitization of ancient architecture as a hybrid archaeological and architectural discipline. These premises varies from case to case, depending of the researching concepts, if work on 3D re-creation follows the archaeological investigations or not, or if the project of 3D visualization is conceived as a tentative study of different possibilities based on so far achieved data or as an attempt in comparative architectural analyses, etc.

As summarized 3D Architectural study, the project for Caričin Grad demonstrates a changing methodology in approach which has evolved in the last fifteen years, following new archaeological findings and progress achieved through interdisciplinary researches.

Key words:
History of Architecture, 3D visualisation, Digital reconstruction (Archaeology), Heritage.

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CONCEIVING OF THE PROJECT OF THE CAPITAL 3D ARCHITECTURAL STUDY OF CARIČIN GRAD ARCHAEOLOGICAL SITE

The term digitization usually refers to two main engagements: works on the rendition of monuments can refer to the creation of a digital image of the existing structure or as incomparably more complex efforts to reach a scientifically valid perception of a monument that no longer exists or is severely damaged. The recording of existing structures is a more technical procedure which primarily documents the state of the monument while the creation of a study in three dimensions tries to reconstruct the emergence of non-existing structures in the digital media. The complexity of three-dimensional studies is reflected in the necessity of mastering both the architectural knowledge and the history of the site and the archaeological research of the monuments as a whole.

Such interdisciplinary knowledge indicates further the need for cooperation between several experts or at least those from two key disciplines: archaeology and architecture. Also the production of serious studies can be accessed on the basis of the published material, but in this case the author must not only master the architectural knowledge

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acquired during schooling but also a special corpus in the field of architecture and construction technology, which is a precondition that also fills a smaller number of experts. Therefore, it is not surprising a long-run odium that less successful projects of 3D restitution of archaeological sites caused among the academic community in the first decade of application of 3D software in promotional projects of the heritage. At the beginning of the 21st century there appeared several projects with some successful works that are often accomplished within the archaeological teams gathered around individual sites, but these projects still do not contribute to the correct perception of the monument they promote, mostly due to the complete omission of architectural studies. The rapidly and often quite incompetent interpretation of architecture creates a counter effect that negatively affects the perception of the monument in public, and calls into question the seriousness of the work of the overall scientific team.

Early phase of the Project – shaping of the working methodology

The first scientifically well-established project of 3D Architectural study in Serbia was the re-creation of the Acropolis at Caričin Grad in 2002 (Fig. 1), initiated and conveyed within the Archaeological Institute in Belgrade[1]. The project was aimed to creating a detailed 3D Architectural study of the walls of the Acropolis of Caričin Grad – Justiniana Prima and all the buildings that once made the “Episkopeion” (Episcopal palace and Cathedral basilica with Baptisterium).within them. The selection of the site and the theme was made in light of the fact that the archaeological site Caričin Grad had at that time disposal of the best survey and planimetric documentation as well as a collection of scientific documentation of several generations of researchers.

From the very beginning, the basic premise in the approaching methodology was carefully scrutinizing of the already existing documentation, primarily architectural planimetry realized by earlier research architects for all fully explored buildings on Caričin Grad.

In this sense, the work on the Acropolis of Caričin Grad with the fully investigated palace and church complex of the Archbishopry of Justiniana Prima (Fig. 2), imposed itself as a clearly defined structural entity, suitable for thoroughly learning and dealing with the architecture of the epoch and the creation of a detailed 3D studies, elaborating them in old 3ds R4 for DOS (1994, Version 4) and Autodesk 3ds Max (Discreet 3dsmax 5). As the archaeological site Caričin Grad was explored with minor interruptions for almost a century (the centennial was marked in 2012), in this significant period of time some portions of the city within the ramparts have been completely researched, like the Acropolis itself – Episkopeion, the zones around the imperial square, the block with the principia, the residential quarter in the Lower Town and the eastern street of the Lower Town with two important churches. Such a degree of research that enabled almost complete ambient perception of certain zones in the urban core of the city, contributed to the conducting of a series of 3D restitution projects that thematically emerged from each other only to fit into the final 3D architectural study of the city.

The character of Caričin Grad as one-layer site and its great significance for historical disciplines, archaeology and history of architecture, from the first project of the Acropolis 2002, indicated the necessity to process the appearance of almost every building in this late-antique city in a thoroughly studied manner, according to all the principles of architectural practices from initial analysis of proportions and design geometry, through the study of the primary structure and volume to the final materialization of the building.

In this process, as well as during the preparation of the planimetric 2D studies, during building of 3D reconstruction, the most effort was invested into elaboration of the monumental sacral architecture along its characteristic cross sections so that the interior of these buildings, as well as their constructive frame, could be convincingly demonstrated.

[1] Project for the Acropolis 2002 was based on an archaeological documentation presented in Duval and Popović [1984a]

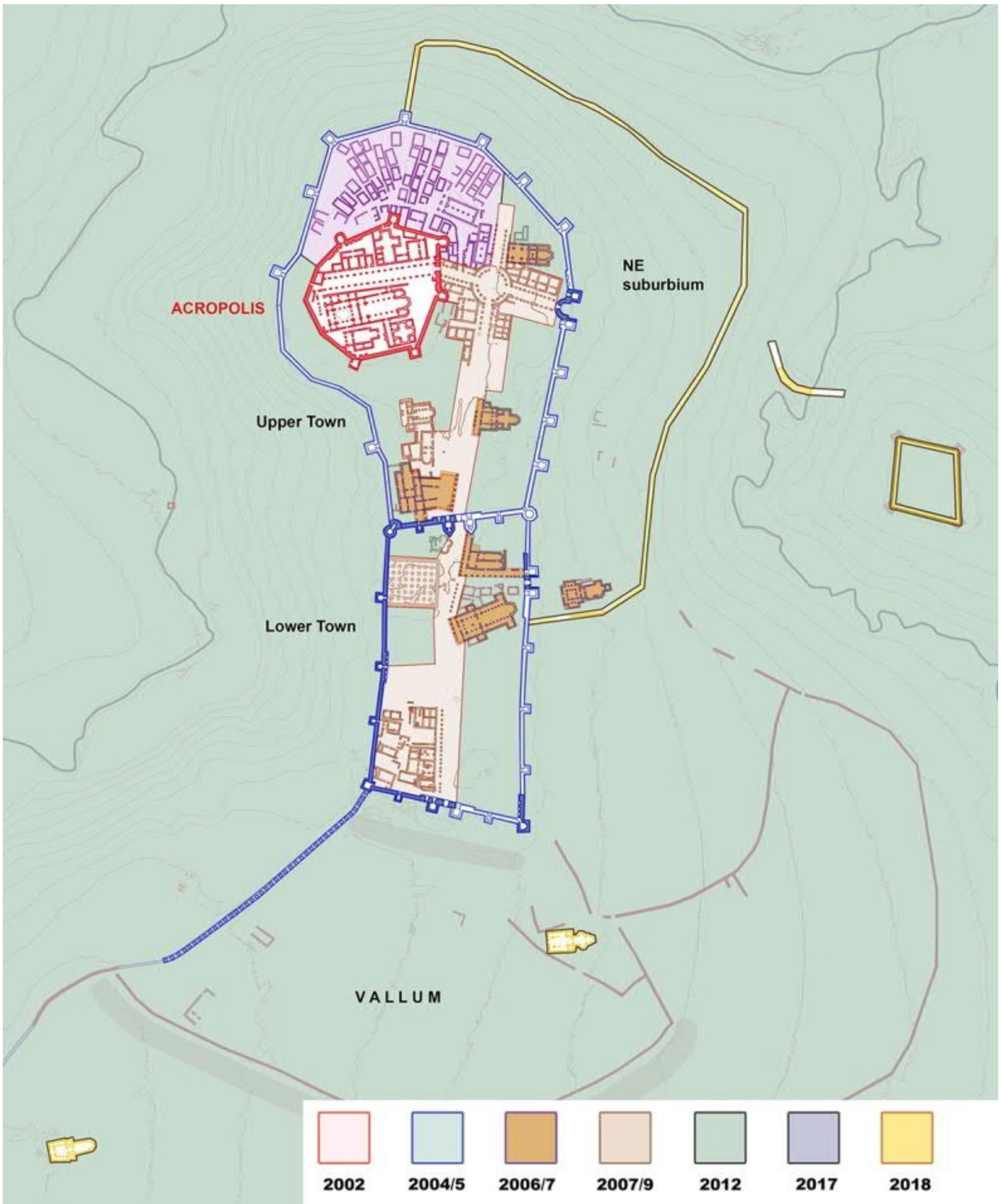

*Fig. 1. Project chronology plan for Caričin Grad – Justiniana prima 3D Architectural Study, achieved in 2001-2018: **2002/3** Caričin Grad – Acropolis Project (main subject Episcopeion of Justiniana Prima); **2004/5** Caričin Grad Study of the fortification works (overall fortification with aqueduct line); **2006/7** Caričin Grad – Architectura Justinianica, Public Edifices (four churches intra muros, principia and the public bath extra muros); **2007/9** Caričin Grad Urban equipment and researched structures (all streets with porticoes, researched settlement in Lower Town and individual buildings); **2012** Caričin Grad – Justiniana Prima Scientific film (landscape and scenery assembling with overall texturizing); **2017** Caričin Grad – Northern slope settlement (complete Architectural Study of the newly researched settlement with horreum and public building); **2018** Caričin Grad – New Skylines: two churches extra muros, outer defense line with river dam and castellum on St Elijah hill. (Drawing V. Zdravković 2018)*

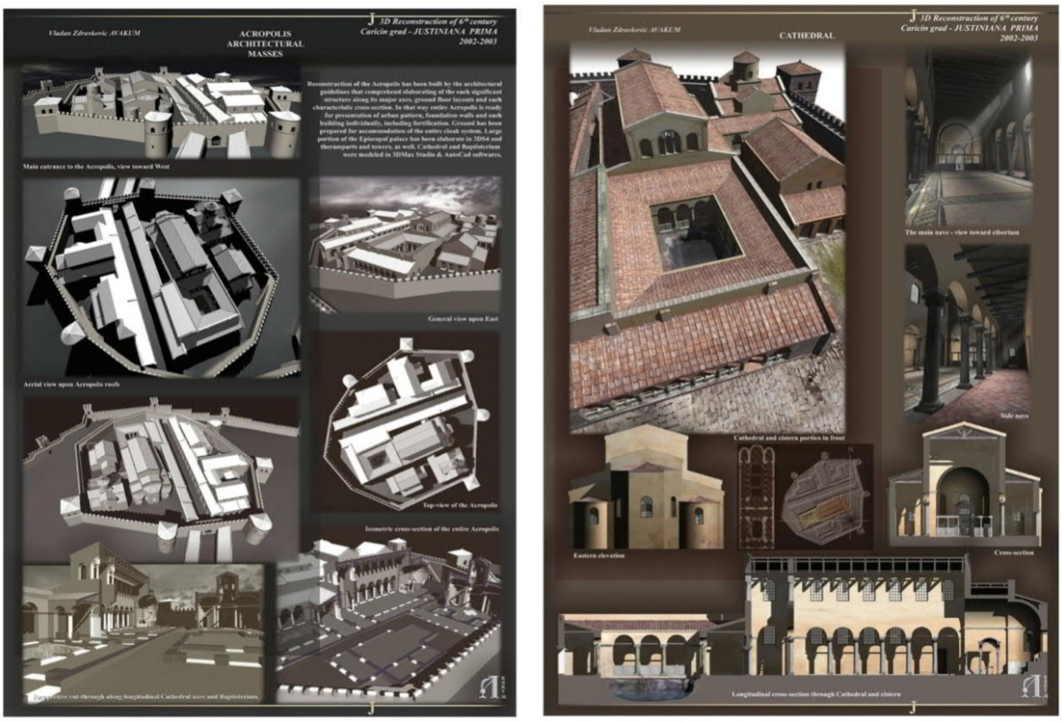

Fig. 2. Caričin Grad Acropolis Project. Volumetric 3D Rendition (left) and fully materialized 3D reconstruction (right) of the Episcopeion (Episcopal palace and Cathedral basilica with Baptisterium). (V. Zdravković, M. Urošević, 2002)

Fig. 3. Caričin Grad Acropolis Project – Elevations of the Cathedral basilica with volumetric and accomplished perspective rendition of the Acropolis from west. (V. Zdravković, M. Urošević, 2002)

In each project adopted working premises were conveyed, which proved to be unavoidable in the process of finding scientifically correct solutions for buildings of different purposes but which shared common architectural pattern of the epoch in which they were created. Guidelines for maintaining the working process during making of the architectural study are:

- Preparation of planimetric and 2D studies according to the architectural principles and on the basis of archaeological research,

- Producing of volumetric 3D documentation,

- Creation of a complete 3D architectural study according to the principles of architectural practice, and

- Complete materialization of 3D reconstruction.

Resulting 3D Caričin Grad database

In this way, the most objective scientific documentation is realized, based on the argued analyses of the constructive structure and materialization of the building by the participation of several competent experts. This process of reviewing the correctness of the perception of architecture lasts throughout the entire working process:

- Preparation of planimetric and 2D architectural studies involves the development of complete architectural project documentation, elevations and display of details of the building that has being studied before building the 3D reconstruction of its appearance. In this step, the greatest number of problems related to the proportionality and the primary constructive frame of the building has been solved, as well as the guidelines for its further materialization in 3D. At this stage, accurate blueprints have also been made for architectural sculpture - capitals, cornices and other tertiary plastics, without which any reconstruction of monumental sacral and palatial architecture loses its credibility.[2]

- Volumetric analysis in 3D refers to the making of the preliminary volume representations of the structure, proportioned and based according to the 2D studies. This was the first spatial visualization of planimetric documentation, and for the first time one could see the relations of certain construction portions and the correctness of the calculated relationships. This step in the 3D study is grateful for demonstrating the primary structure of an individual building but also for spatial analysis of the entire urban agglomeration and its relation to topographical conditions, hydrological situation and morphology of the terrain. Also, at this stage, many final solutions to the appearance of architecture have not yet been fully demonstrated, and the demonstration of primary volumes may at some point be considered scientifically "abstained".

- Further development of volumetric 3D documentation refers to the creation of a detailed structure in 3D[3], with a complete demonstration of the overall constructive assembly and final processing of architectural sculpture and profiled elements (Fig. 3). For most of the scientific projects within which scientific conclusions and solutions are demonstrated, this degree of processing is of most benefits, before accomplishing of the final materialization of the 3D Reconstruction (Fig. 4).

- Complete materialization of 3D reconstruction refers to the creation and application of convincing and scientifically acceptable textures that achieve not only the reality of the rendition of the elaborated building but demonstrates the technology of building and knowledge of the architecture of the epoch. There are many examples that successful 3D reconstructions in its final processing are degraded by the producing and applying bad or incorrect textures, which again causes a poor perception of the monument and rejection in scientific circles.

[2] Where it is possible, of course, it is always of great benefit to involve some of very new scan-digitization techniques, laser scan or photogrammetry or a combination of the digital and analogue technology as it was successfully applied in the work of Athanasios Styliadis [2007].

[3] A good example of elaborated volumetric 3D re-creation of the architecture would be the volumetric spatial model of the interior of the church of Hagia Sophia, built for the purpose of lighting analysis and demonstration of Justinianic liturgy. [Stichel and Svenshon 2008].

CARIČIN GRAD PROJECTS 2006-2008 – ASSEMBLING OF THE TOWN IN 3D: DEVELOPING OF THE MASSIVE 3D STUDY OF THE 6TH CENTURY URBAN AGGLOMERATION

Of course, 3D reconstructions can be elaborated to different levels of detail and expertise which again depends on the character of the monument, its significance in science, and the attitude and ambitions of the scientific team. The 3D architectural study project for Caričin Grad has been composed from the very beginning as a long-term composite study, which primarily provides detailed 3D architectural documentation of the already thoroughly studied parts of the site and in the next steps the newly investigated portions of the ancient town.

As the first in a series of projects, the 3D study of the Acropolis in 2002[4] marked the direction in which the construction of the overall 3D study of the site will go. During the realization of this project, the guidelines which must be respected in order to achieve scientifically valid and prestigious 3D material have occurred as well.

Fig. 4. Caričin Grad – Study of the fortification 2004/5. Volumetric rendition with elevations (left) and cross-sections of the fortification of Upper Town and Water tower (right). (V. Zdravković, 2004/5)

This primarily refers to the scrutinizing of the architectural and urbanism solution of the late antique site, where a step forward was made in correcting then current perception of the appearances of the Caričin Grad architecture as rather medieval into early Byzantine. Profound studies of the investigated architecture of the site, with their own appearances gained in 3D reconstruction projects, also have provided certain contributions to today's widely accepted picture of this endowment city of Emperor Justinian I as a late antique metropolis erected *de novo*, with the seat of the archbishop and the martyrial complex within the ramparts. A large number of various church buildings[5] within the urbanized core in the walls (ten churches and a small bath adapted at a later stage in the eleventh church building), required a particularly studious approach primarily in studying the typology of early Christian church architecture, and then in the elaboration of churches in 3D, because almost every church building on Caričin Grad was equipped with its own sculptural program. More edifices from the public works corpus are also extremely important from the point of view of the history of architecture and have been subject of detailed study in the process of making of their planimetry and study analyzes.

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[4] 3D Architectural Study of the Acropolis 2002 was presented at Exhibition at French Cultural Centre in Belgrade in 2003 and 2008. [Bavant and Ivanišević 2003; Ivanišević 2008].

[5] The results of excavations and further analyses of the most important church ensembles within Acropolis walls are gathered within [Duval and Popović 1984].

As a completely justified step after the 3D study of the Acropolis of 2002, the next project for CaričinGrad 2006-7 was conducted (Fig. 5), with urban portions of the town as not processed as a whole, but with individual buildings chosen instead, from the group of public works (*principia* and large *thermae*)[6] together with four church buildings, each different by their architecture design. With this project (Architectura Justinianica), a significant step forward was made in dealing with the late-antique architecture of Caričin Grad, because the entire process of developing of individual 3D architectural studies was based on previously detailed planimetric analyzes and designs. Together with the project for Acropolis, the 2006-7 project brought for the first time detailed 3D studies of the monumental architecture of church-sacral buildings, hydraulic structures and examples of the military architecture of the epoch of Justinian I, designed and materialized as an Imperial project on the soil of central Illyricum at the beginning of the sixth century. The collection of all structures elaborated in the form of a study in 3D from 2002 to 2008 was done during the project for Caričin Grad 2008, when for the first time all individual steps were integrated into a massive 3D study of the city as a whole. Caričin Grad is not a large-scale settlement, but its 3D study became a massive 3D scientific material file[7] because, apart from the exterior of their architecture, all important objects of the late-antique metropolis are elaborated in detail as well as the interior with the accompanying architectural sculptures. (Fig. 7) It is indicative that the sculptural irregular form of a richly decorated capital processed as a 3D model, occupies almost identical technical capacities - the number of bits equal to the 3D model of the building without incorporated sculptural plastics.

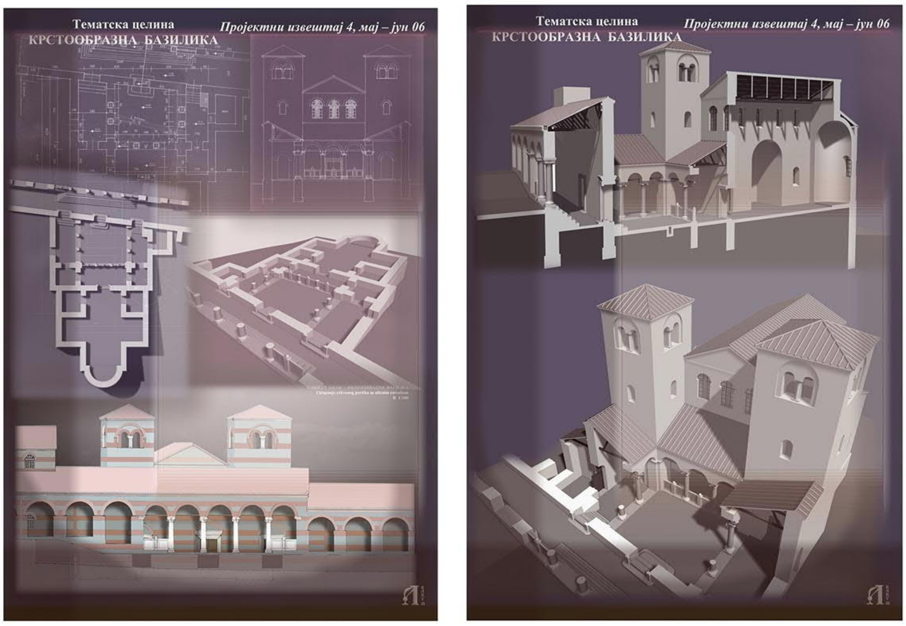

Fig. 5. Caričin Grad – Architectura Justinianica, Public edifices EAR 2006/7. Planimetry and different stages of the volumetric 3D rendition of the Cruciform church. (V. Zdravković, M. Urošević, M. Novčić)

The project of the final 3D study of Caričin Grad 2008 was completed without the final materialization of the appearance of the 3D reconstruction, more precisely without the application of correct and studied textures for buildings and topography of the environment.[8]

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6 For project 2006 a basic archaeological documentation was given by Bavant et al. [1990].

7 Managing and preserving of this digital database refers to the next level of the long term arranging achieved documentation in 3D which comprehends data classification along some basic categories and principles, some of which (semantic and geometric enrichment) have been suggested within [Beets at al. 2016].

8 As assembled 3D Architectural Study Caričin Grad was for the first time presented at the Exhibition "Byzantium-Splendor and Everyday life", Bonn Art & Exhibition Hall, Bonn 2010.

The complete materialization of the 3D study was carried out in a special project of Caričin Grad - Justiniana Prima 2012, which was designed not only to improve and complete the realistic appearance of 3D studies, but also to produce a scientific film in the form of an animated rendition.[9] The last city quarter, which has been fully elaborated and as a whole was incorporated into the final 3D study of the Caričin Grad, is a project of the 3D architectural study of the settlement on the northern slope of 2017. A display of this city district, located on a slope north of the Acropolis and around the *horreum*, demonstrates the results of several years of archaeological excavations by which not only the urban appearance of this part of the city was completed, but also an insight into a distinctive and unexpected type of housing and arrangement of residential areas within the walls of the protected area of the Upper Town, was provided as well.

Fig. 7. Caričin Grad – Architectura Justinianica, Public edifices EAR 2006/7. Planimetry,volumetric and final rendition of the capital – architectural sculpture. (V. Zdravković, M. Novčić)

The massive 3D repository (Fig. 8) the final 3D study of Caričin Grad –Justiniana Prima in the past one and a half decade has grown to, is an example of the assembling of the scientifically scrutinized and validated resource of materials elaborated in 3D, eligible for multipurpose use in the most diverse scientific endeavors related to the Caričin Grad site itself or to support projects related to the epoch of late antiquity and the early Byzantium.[10]

CONCLUSIONS

Dealing with architecture of historical heritage in 3D is a hybrid scientific engagement based on the expertise of two basic disciplines - archaeology and architecture. In this sense, on the one hand, development of multimedia technologies (mm) and, on the other hand, experience in this field over the past two decades, points to the necessity of adopting new terminologies or better definitions of already wide spread terms defining the nature and purpose of such projects.[11] First of all, this refers to the delineation of scientific projects from the

[9] An improved study of the town from 2010 was achieved in a separate project 2012 and presented at the Exhibition of „Golden Byzantium and Orient", Schallaburg Castle, Lower Austria, April-November 2012. Producing of the scientific film for 3D Caričin Grad 2010 and 2012 was provided and supported by the Römisch-Germanisches Zentralmuseum (RGZM) in Mainz.

[10] As more actual than ever before, the issue of long term maintaining 3D database appears to be a matter of the current debates among scholars. One approach to the problem is exposed in: [Paquet and Viktor 2005].

[11] For terminology articulation and semantic database see Kuroczyński et al. [2013-16].

widespread popular semi-scientific or quite arbitrary works that are mostly represented in the global media and which can be properly grouped under the term visualization.

Fig. 8. Caričin Grad – Justiniana Prima Scientific film 2012. An overview toward the south perimeter of the town. (V. Zdravković, M. Urošević, M. Novčić, V. Ranđelović)

Visualization[12] would mark in the 3D world what the illustration (better or worse) would be in the world of books, therefore without pretensions to have a serious project format but good enough to illustrate selected topics in the public media and popular publishing. Scientific projects for treating historical monuments in 3D should range from architectural restitution to even more serious, scientifically most valid, 3D reconstructions. Architectural restitutions may also vary depending on the available knowledge of the monument, from completely hypothetical and tentative to study restitution. In their reach, these projects aim to introduce new views of monuments in scientific discussions or to test certain scientific ideas about the elaborated topic. Architectural restitutions are therefore preliminary studied views of architecture that can relatively quickly change according to the new knowledge.

In contrast, the architectural 3D reconstruction of the monument is the most solid presentation of the chosen structure, which is based on long-lasting and deeply studied scientific work, as well as on the results of the architectural study, which implies its long presence in an unchanged form in the official scientific flow. Similar to the categorization of projects in 3D, a difference in the work process can be deducted, as well. For planimetric or 2D studies, we can talk about drafting and drawing while working on the elaboration in 3D is truly "building" of architectural displays, because the author is all the time focused on thinking and solving volume in three-dimensional space.

All of this documentation could be realized in various multimedia software for 3D modelling. In the Caričin Grad project the basic software was Autodesk's 3ds R4 for DOS (1994, Version 4) and Autodesk 3ds Max (Discreet 3dsmax 5 - Autodesk 3ds Max 2012). All textures were elaborated in Adobe Photoshop (Adobe Photoshop 8.0, CS 2 – CC 2015). The primary goal of the project was the exchange of ideas among scholars therefore purely academically with no intentions to exploit the results in wide range promotion of the monument. Nevertheless, achieved quantity and scientific quality of the material opens the question of further upgrading or using it for the

[12] Visualization could be achieved via various technologies and could refer either to the simple archive document or rendition and scans of smaller artifacts as well [Gonizzi Barsanti et al. 2015].

projects of Virtual and Augmented Reality, which again could bring another level of experience of the architecture already elaborated in 3D.

Each of these documents has its own individually purpose while unified gives a total massive architectural study of the monument considered. For the sake of scientific approach and control of the work process, it is necessary to adapt the degree of documentation processing to the knowledge about the monument and its significance for science and the public. In this sense, for the most devastated monuments or for those structures for which there is insufficient information, it is enough at least from a scientific point of view, to reach volumetric presentation and rendering with somewhat more elaborate structures for which there is more data. All other more complex, more significant and better explored or sufficiently documented monuments deserves a serious scientific approach with the gradual developing and production of scientific 2D and 3D studies. Reconstructing the past purely in words is a challenging and difficult task by itself. The reconstruction of the appearance of the extinct monument with all its accompanying argumentation often turns into the work of several generations of experts, because it entails the responsibility of presenting historical and monumental heritage in the most valid and objective way to the general public. In the light of the increasingly progressive and inspirational works in the field of architecture history, new questions arise about the institutionalization of these achievements to the benefit of science and the generations of followers of this noble discipline.

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Cultural Heritage Preservation of Pre-Mongol Rus: Reconstruction of Lost Stories. White-Stoned Carved Reliefs of the St. George's Cathedral (Yuriev-Polski Town, Vladimir Region, Russia) of the XIII Century

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Svetlana BORISOVA, Yuriev-Polski Museum of History and Architecture, Russia
Sergei KARTASHOV, professional architect and restorer, Russia

St. George's Cathedral is one of the most well-known monuments of Vladimir-Suzdal Rus. It was built in 1234 and became the last example of pre-Mongol white-stone architecture. The unique feature of the cathedral is the carved white-stone décor which themes are those of Christian iconography, pagan images and floral ornament. In the second half of the 15th century the cathedral fell and later was restored, but the integrity of stone reliefs was lost. Later the reliefs were restored by artisans of Vasiliy Ermolin, an architect from Moscow, in random order. During the reconstruction the temple became lower, lost its original proportions and the unique ornament; the proper way of white-stone history was forgotten. Many reliefs were lost while the others were used as the constructional material for the restoration. Some stone reliefs can be found in the cathedral masonry under the temple roof or in the columns. Inside the building one can see reliefs which have not been used by masters during reconstruction. Researchers have attempted to plan the reconstruction of the cathedral many times, but the oddness of reliefs and their multiple damages complicated this work. Modern information technologies (such as laser scanning, photogrammetry, 3D modeling programs and BIM) may be useful for solving the problem of reconstructing the cathedral original appearance and lost ancient themes as well as testing the cathedral reconstruction hypotheses at hand. Digitization of stone reliefs allows the researcher to work with their original look and proportions in digital format preserving the integrity of the object. One of the results is the software environment developed by the authors to systematize stone reliefs. Within this environment the authors have reconstructed some lost mythical and biblical themes of stone reliefs located on the cathedral walls.

Key words:
Architecture, Museums, Cultural Heritage, 3D-reconstructions.

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HISTORY OF THE MONUMENT

The objects of cultural heritage in Russia have a great historical value for the state and society. Russian architecture includes various forms and styles historically predominant in different epochs. The problem of saving the heritage of the ancestors is urgent, especially for the monuments of the Ancient Russia. The condition of the eldest buildings becomes worse and the restorations bring little help. Some of the historical buildings were reconstructed one or more times, their first look was lost. This fact attracts a lot of students from different fields of study.

St. George's Cathedral (Vladimir region, Russia) (Fig. 1) is a white-stone monument of Pre-Mongol architecture. It was built in 1234 by Svyatoslav, the Great Duke of Vladimir. The time the temple was erected was the time of feudal disunity and fraternal strife in Russian lands. The battle of Lipitsa [Nasonov 1950] in 1216 was a flagrant example of internal disorders destroyed many people and weakened Russian state. As some historians say, the battle of Lipitsa shocked Svyatoslav and led him to the great penance. St. George's Cathedral could become one of the displays of his great pain and repentance. This suggestion is only hypothetic, but it can explain the appearance of such a monument in Vladimir region just before the Mongol invasion.

The cathedral was decorated with artificial carvings of saints, biblical scenes, animals and mythical creatures. The decorations formed a storyline, where every component was included with a special meaning. But from the second half of the thirteenth century to 1470 the temple broke down; the storyline was mixed. In 1471 a merchant and architect from Moscow, Vasiliy Ermolin [Voronin 1974], rebuilt the temple in his own way, but the previous look of the building changed. Moreover, the pictures from the walls were mixed in random way and placed back chaotically. First meaning of the decorations was lost.

More than 100 years enthusiastic researchers are trying to restore the first look of the temple. One of the first works about St. George's Cathedral was written by architect K.K. Romanov in 1910 [Romanov 1910]. He described the condition of the temple itself and made some attempts to unite the destroyed composition. As a result, the first reconstruction, 'The Transfiguration of Jesus' appeared. He used clay for making models, the picture of his reconstruction became popular among the next students.

The second researcher of the cathedral was Piotr Baranovskiy. He made complete reconstruction of the cathedral, got rid of the later buildings around it and opened the way for all the reliefs on the facades. He tried to make some reconstructions placing images of the reliefs on the plans of his variant of reconstruction. He did not publish his works, they now remain in archives.

One of the most well-known architects investigated the cathedral in 1950-1970, were N. Voronin [1974] and G. Vagner [1964]. The former completed the historical review about the cathedral and thoroughly studied the elder sources. The latter paid more attention to the carvings and their correct placing. Vagner used his own drawings for the reconstruction. Both architects had their variants of reconstruction of the whole cathedral.

A. Stoletov in 1980s was the major restorer who had the access to the cathedral. His work was oriented on the reliefs, but he was also interested in constructional features of the building. His reconstruction model differs from Vagner's variant, but both did their reconstruction plans based on hypothesis.

As the documents say, the cathedral was restored many times. The first one can be traced back to 1270s, when the annex of Trinity was erected. It was a small outbuilding by the northern facade of the temple. According to the previous studies, the annex was built as a shrine for the Grand prince Svyatoslav. Later it was enlarged and transformed to the Cathedral of Trinity, the warm temple that could be used in winter. The second restoration was made by Ermolin, as it was already noticed. Russian architect Piotr Baranovski appreciated that only the ground tier of the St. George's Cathedral remained untouched. There is also a suggestion that a main part of the internal structure including arcs can be considered as original, but there is no information which could clearly prove this hypothesis.

Afterwards, during the period from the XV century to the 1920s the temple had many household extensions (partly wooden), the bell tower, and its territory was rearranged for many times. In 1920-1930 Piotr Baranovskiy made a complete reconstruction willing to bring the cathedral back to the look of 1471. He destroyed the bell tower, disassembled the outbuildings including the Cathedral of Trinity. All his actions were pictured and now can be found in his personal funds in Schusev State Museum of Architecture (Moscow). The actual look of the temple is a result of Baranovskiy's work. The next reconstructions made by N. Voronin, G. Vagner and A. Stoletov were focused on securing the current condition of the cathedral and researching its history. The latest integrated research was made by S. Zagraevskiy in 2009.

Zagraevskiy made a complete review of the models offered by the previous scholars and made his one. His work was concentrated over constructional plans; the carvings were not the core of his interests.

The methods used by previous researchers cannot give us the key answer that could be proved by existing facts: how did the temple look like before the reconstruction and why. Here are some methods used by the previous researchers:

1. The method of drawing the reliefs and making the reconstruction on paper. This method can be vulnerable because of the idealistic way of drawings usually offered by the artists. The actual carvings can have more defects and cannot be matched, but on paper they are easily connect to each other.
2. The method of picturing reliefs with camera and making photographic images. This method is the most complicated, as the orthographic projection of the image is hard to be made using only a camera, but also every carving should be pictured in the same conditions as the others. Moreover, it is hard to work with many pictures simultaneously.

3. The method of reconstruction of the reliefs by using clay models. This method is most reliable of the presented, but it requires a lot of clay, forms, free space for storing the models.

As it can be seen, the presented methods are far from ideal for the reconstruction works. Modern technologies can be a helpful instrument for the reconstruction.

METHODOLOGICAL SOLUTIONS

The main difficulty in the tasks given earlier is that all the stone reliefs are mixed in random way. Moreover, not all the stone pictures and figures can be found on the facades: some part of them was placed into the masonry of the cathedral. The proof of this fact was discovered by Sergei Kartashov under the roof of the temple. The actual condition of the hidden reliefs can be seen on Fig. 2. The number of carved stones cannot be appreciated without the special instruments, such as X-ray scanning. The previous researchers had no choice but to work only with the available carvings. The main advantages of using modern technologies will be described later.

The methods used by the researchers of the XIX-XX century were useful for their time, but now they are not enough for modern science. G. Vagner [1964] used drawings for making the integrated pictures. K. Romanov made clay model and restored the lost carvings. The other researchers used pictured images of the walls. All those methods have their weaknesses: none of them can present the full and exact model of the stone, except Romanov’s one, but it requires patience, time and huge amounts of materials. The existing reconstruction models were made based on unfulfilled data. There is much more to explore yet. The authors of this article began this study having the aim of working out some extra knowledge, inaccessible for the previous researchers.

A new investigation of the cathedral required new technological ways of study and interdisciplinary methods. Only this way was proper for a new research. The group worked out the plan of the research, which included:

1. Finding the information about the temple in elder sources (monastery catalogues, chronicles) and their integration with modern researches.
2. Analyzing the existing reconstructions of the St. George’s Cathedral made from the end of the nineteenth century to these days.
3. Making a complete digitization of all the outdoor surface of the temple using photogrammetry.
4. Creating a bank of 3D-models of all the carvings based on the photogrammetric materials.
5. Scanning the carvings in funds of Yuriev-Polski museum with special laser-scanning hardware.
6. Finding the appropriate way of x-ray scanning of the temple walls and work out the solution of the problem of internal spaces.
7. Developing the interactive software for working with the bank of models.
8. Linking the carvings to their descriptions and creating the database of the carved stones.

The first problem faced by the authors was the problem of working with whitestone reliefs. Their mixed condition required the collecting of all existing carvings and creating the bank of the images or models with descriptions. Some works for deciphering the carvings were made earlier by Romanov, Baranovski and Vagner, but there was no integrated base of the images. The first step was the digitization of the outdoor surface of the temple. The authors decided to use photogrammetry as the most simple and accessible way of digitization. Using about 5000 images taken by professional cameras and drone DJI Phantom 3 Pro, a point cloud of 90 million points was created in Agisoft PhotoScan.

The previous step helped to form the full-size model of the cathedral and carry out measuring works. When all the works with the whole point cloud were finished, every facade was formed as an independent point cloud with higher point density. Every carving cold be clearly seen and saved as an independent textured mesh. This kind of mechanic work carried out 200 models of whitestone carvings. The results are available on sketchfab.com[1].

The second step was the deciphering of the reliefs on hand. Even now it cannot be finished as not all the existing reliefs were found. But some of the compositions and independent carvings were found using the previous works

[1] https://sketchfab.com/jekelon/collections/saint-george-cathedral-yuryev-polsky

and elder sources. The main problem of working with many carvings placed to one project emerged in case of limited hardware resource. The computers of the students could not accept 10 or more models imported to 3DsMax, SketchUp or Blender. The group had to work out another way of analysis.

In December 2017 Ivan Trishin and Denis Zherebyatyev created the first example of interface necessary for the project [Trishin 2018]. Its main idea was to use textured meshes of whitestone carvings collected from photogrammetry like puzzle elements. The new software based on Unity3D game engine was developed for the special aims of the research presented. The meshes were placed into box triggers (user's interaction with objects is possible using them), and C# code was written. When the cursor is pointed onto the carving, a boolean variable changes to 'true' value and the carving can be replaced. When users put left mouse button down having aimed to the carving, the model can be taken anywhere on the desktop, it follows the cursor. Middle mouse button gives possibility to rotate the model around Y-axis. The executable file was tested on the computers with middle-level characteristics and the result was satisfying for the working group.

The interface of the software was designed in the simplest way to provide users with comfort working conditions. In the center the main field was placed. Here users can move and rotate the models of carvings and join them together. The left sidebar contains the bank of all the carvings grouped by their meaning (saints, animals, mythic creatures and the other). The model can be created in the center of the working field by clicking the necessary knob in menu. The sidebar under the main window has various reconstruction models worked out by the previous researchers, and an empty field. The fields can be changed by clicking appropriate button. The right sidebar presents the instruction for the program. Now the software is being tested and improved by specialists. The nearest plan for the improvements is to add 3D model of the cathedral as a working field. Here are the main functions of this program:

1. Adding model. User can choose the model he needs in the left sidebar and add it to the main field.
2. Moving and rotating model. Left mouse button pressed when the model is under cursor replaces the model, middle button rotates the model over Y-axis.
3. Deleting model. While the cursor is pointed on any model, user can press 'delete' button and the model will be deleted from the field.
4. Choosing the image of the field. There are variants of reconstruction proposed by Vagner, Stoletov, Voronin and Zagraevski, the plans of current condition of the cathedral and an empty field.

Nowadays the software is being used inside the group. The application will be ready for beta-testing when all the errors and bugs are fixed, and its toolkit will be widened for more complicated tasks.

THE ANALYSIS OF CARVINGS

The models collected during the digitization were linked to the sources having any information about them. The pictures contain two or more stones were analyzed first. Compositions "The Ascention of Christ" and "The Transfiguration of Christ" were described by Vagner and Romanov. Each part of the compositions was completed with the description and placed to the right position. The central parts of these compositions present Jesus Christ, there were also independent portraits of Jesus identified.

The Godmother has her own place in some carvings, she was placed to the center of composition "The Godmother and warriors". In prophetic rank of the altar (first described by Baranovski and drawn by Vagner) her image with little Christ also takes the central position. The elder prophets are placed by both sides of the Godmother. The first of them are elder kings of Israel: Solomon and David. For the next positions images of prophets Isaiah and Ezekiel were taken according to the canon of the prophetic rank. There are only two great prophets of four but using the written descriptions and iconography the group of researchers found the other ones. Jeremiah and Daniel were added to the whole composition by elements of decorating carvings matching on borders of the stones. Thus, the composition was enlarged from four elements to seven.

The other kind of decorations was presented by row of people and lion heads, the latters were pictured fire-breathing. The decoration was identified as the image of people and chimeras, as the latters were found in mythic literature of elder Russia. There were also found some pictures of dragons, birds with women faces (syrins), lions, an elephant and a cat. Many of pictures of saints and martyrs were not described clearly, but all of the pictures of angels and archangels were identified. From all the facades there were 200 carvings found, identified, and structured.

According to Vagner's reconstruction, the arcade belt formed around the facades included the carvings of saints, archangels and martyrs. Today only 16 images of arcade belt can be found. Some stones are not included into this row, but hypothetically they had their place in this row. Nevertheless, the reconstruction offered by Vagner requires about 50 parts of arcade belt, which are far from being found on the facades. This hypothesis is now under discussion. 22 images of martyrs were described by Baranovski, by this thesis is also hypothetic.

The carvings found by the authors can be formed to the next list:

1. 155 saints, angels and compositions
    a. 6 archangels.
    b. 2 images of praying Godmother.
    c. 10 angels.
    d. 22 rounded martyrs (according to Baranovski)
    e. 16 saints in arcade belt.
    f. 3 images of Edessa.
    g. 7 images of the composition 'The Ascendance of Christ'.
    h. 25 saints hypothetically identified as prophets.
    i. 3 martyr warriors.
    j. 2 images of Old Testament Trinity.
    k. 4 images of composition 'Seven Sleepers'.
2. 45 animals and mythical creatures
    a. 9 gryphons.
    b. 5 syrins.
    c. 8 lion faces.
    d. 7 lions and cats.
    e. 2 birds.
    f. 10 images of decorative belt with chimeras.
    g. 2 wolves.
    h. 1 elephant.
    i. 1 centaur.

All the images found remain in different conditions and sometimes it is uneasy to compose the carvings in proper order. Often the apocryphal stories help to connect some plots to each other.

PLANNING THE FUTURE

The actions described above are only the start of the job. The first task to be done next is to digitize the carvings secured in funds of Yuriev-Polski museum. About 70 blocks are secured in the attic and can be reached only with special conditions of investigation. The second actual problem is the massive of stones secured inside the walls of the cathedral. The space between the roof and the arcs is enough to be studied and digitized with laser-scanning hardware or by photogrammetry, but the preparation works are also can be done only in the conditions of warmer weather.

Laser-scanning works are necessary not only for making the model of under-roof space, but also for linking the indoor and outdoor space. The question of the structure of walls is now still opened, as there was no researcher able to do such kind of work with the traditional methods. Nowadays no one knows how many reliefs are secured inside the walls. The thickness of the walls and its difference all over the facades will be helpful information for next studies. The negotiations with laser-scanning company are still in an active phase, thus according to the plans the laser-scanning of the cathedral will start in April 2020. The meshes created by scanner will also be useful for the improvement of the existing models with higher quality. The main task for the laser-scanning is to get integrated meshes of all the surfaces of the cathedral in actual size. When the model is analyzed, the next step will begin.

One of the perspective ways of studying the ancient buildings is X-ray scanning. In December 2017 an article ‘Discovery of a big void in Khufu’s Pyramid by observation of cosmic-ray muons’ was published in Nature journal [Morishima et al. 2017]. The experience of using x-ray technologies in pyramids helped the researchers to investigate the internal structure of the object without penetrating it. This research became a well-known example of a new method of study in archaeology and architecture. Another example was presented in ‘Virtual Archaeology-2018’ conference in Saint Petersburg by Alexander Kulkov and Maria Kulkova. The report ‘Use of X-ray 3D-microCT for archaeological artifacts’ investigation’ was dedicated to studies of small archaeological forms with 3D-microCT technologies. The possibility of using x-ray technologies for investigations of large and small forms gives great opportunities for modern science. Many objects of cultural heritage need to be thoroughly studied, but their internal structure is still hidden from the eyes of scholars.

St. George’s Cathedral can be defined as one of the most complicated and mysterious building of whitestone architecture of pre-Mongol Rus. Even Baranovski and Stoletov new little about the internal structure of the building, though they both made restoration works. Before the technologies of X-ray scanning the only way to study the space inside the walls was to disassemble the temple. The information about the structure of the cathedral is as necessary for the next studies as vital for the restoration works.

All the steps described earlier are necessary for HBIM-modelling which can be helpful for modern restorations. Using the models worked out from photogrammetry, laser-scanning and X-ray tomography, the researchers will have an ability to construct both the modern appearance of the cathedral and its hypothetic condition of 1234. The model with the descriptions and documents will help next restorers to keep the cathedral in good condition, to predict problems and solve them in advance. Nowadays we have only approximate plans made by hand. The integrated HBIM-model will also be interesting for the researchers unable to get to the object.

CONCLUSION

To sum up the results, it should be noticed, that the process of the investigation depends on the weather. The rules of the museum stated that lower temperatures automatically close any access inside the cathedral and to the funds. The work with the object itself carries on only in warm part of the year, thus the whole process slows down. But for today the group of the researchers managed to get to the next results:

1. The whole outdoor surface of the cathedral was digitized and analyzed in special software. The point cloud of the cathedral was created, the carvings were selected and worked out as separate objects and stored for Unity engine. The software was developed for the aims of reconstruction and used for arranging carvings in proper order.
2. The massive of written sources and previous works was observed and the carvings were depicted. The meanings of the images were collected from various written sources of Christian and pagan origin. These descriptions were necessary to work out the concept of compound plots.
3. The bank of carvings was published on sketchfab.com. The open-source databank may be interesting for specialists in archaeology, iconography or elder history of Russia, and some new and interesting concepts can emerge.
4. New ways of study were tried and negotiations with laser and X-ray scanning companies are opened. The last word of 3D-digitization widens the possibilities of the research and helps to discover the information inaccessible for the previous students.

These results are only the first ones in a grand project oriented on the full investigation of the cathedral. The work over St. George’s Cathedral never stops. Some architectural museums are already interested in this project and soon the exhibitions about St. George’s are likely to be opened. The object attracts many people, not only scholars, but also tourists and native people of Vladimir region. The hope that this unique monument of whitestone architecture will flourish is still alive. And there are many people working over it. The group of authors hopes that this article will be helpful for students searching for the solutions connected with their 3D-projects.

The necessity of using modern technologies in archaeology, architecture and history is undoubted. The first examples of 3D-modelling were attracting the scientists in early 90s, working with great massive of data were described even earlier. Nowadays computer abilities are close to be endless. The moment of using them for enlarging the knowledge is now. It unites people of different professions, helps them to start discussion and find the truth. The field of study not affected by digitization and computerization can become dead soon. But new abilities open the doors of new knowledge for us. And refusing it means staying in the dark.

FIGURES

Fig. 1. St. George's Cathedral (photo by I. Trishin, 2016)

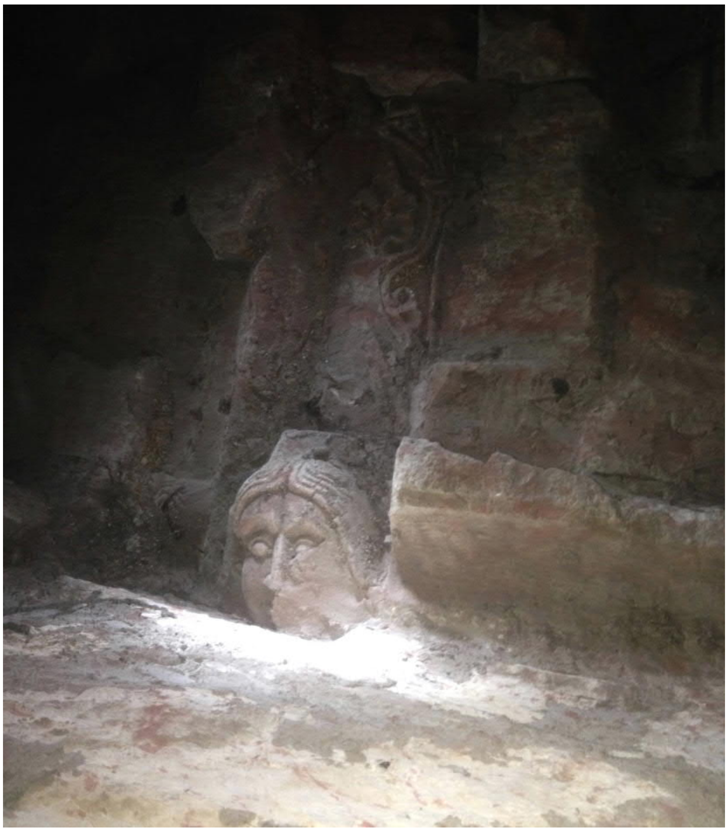

Fig. 2. The masonry of the cathedral with whitestone reliefs (photo by S. Kartashov, 2016)

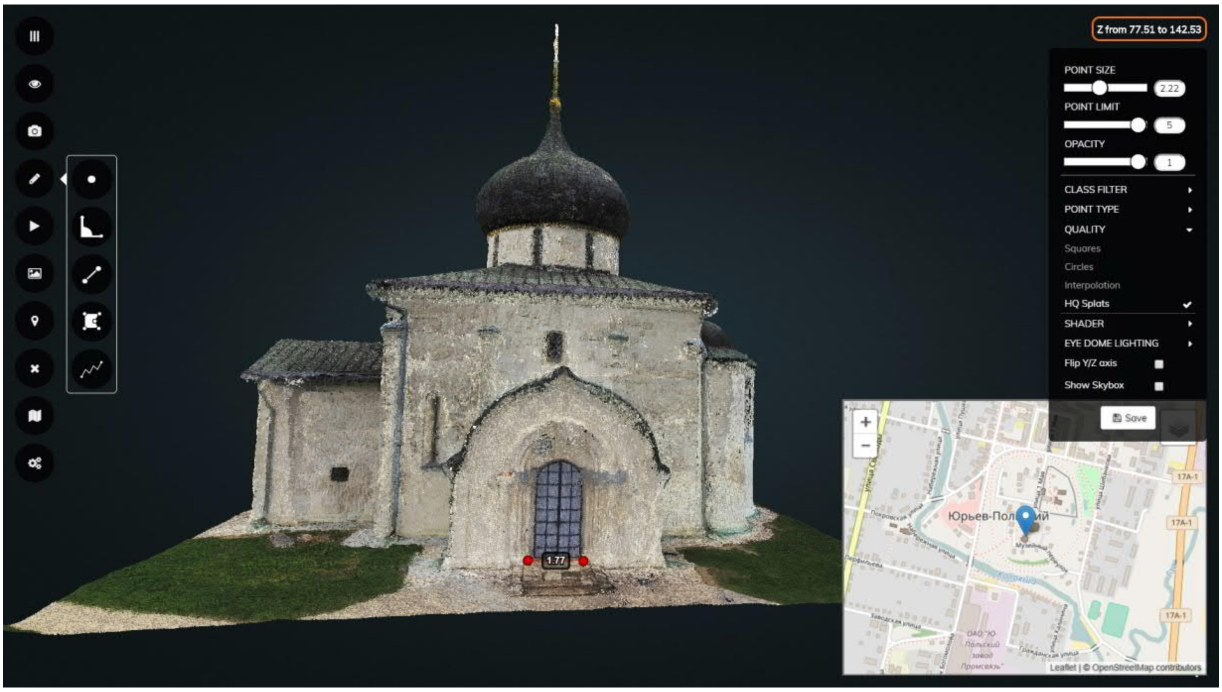

Fig. 3. Point cloud of the cathedral in Pointbox.xyz (screenshot from https://www.pointbox.xyz/clouds/595ffebecbcb7a0f94dd58b4)

Fig. 4. Textured model of the group of stones from the south façade (screenshot Agisoft PhotoSkan working process)

Fig. 5. 3D-models of carved blocks with the measure scale (screenshots Agisoft PhotoSkan working process)

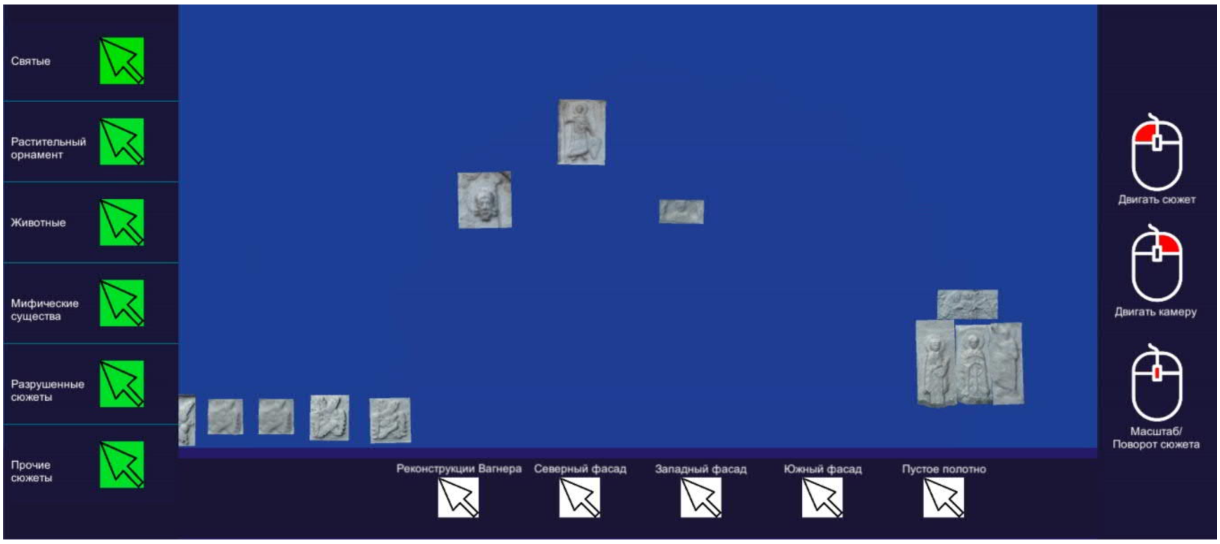

Fig. 6. Software developed for the reconstruction (screenshot from Unity3D Game Engine project)

Fig. 7. 'The transfiguration of Jesus (screenshot from Unity3D project)

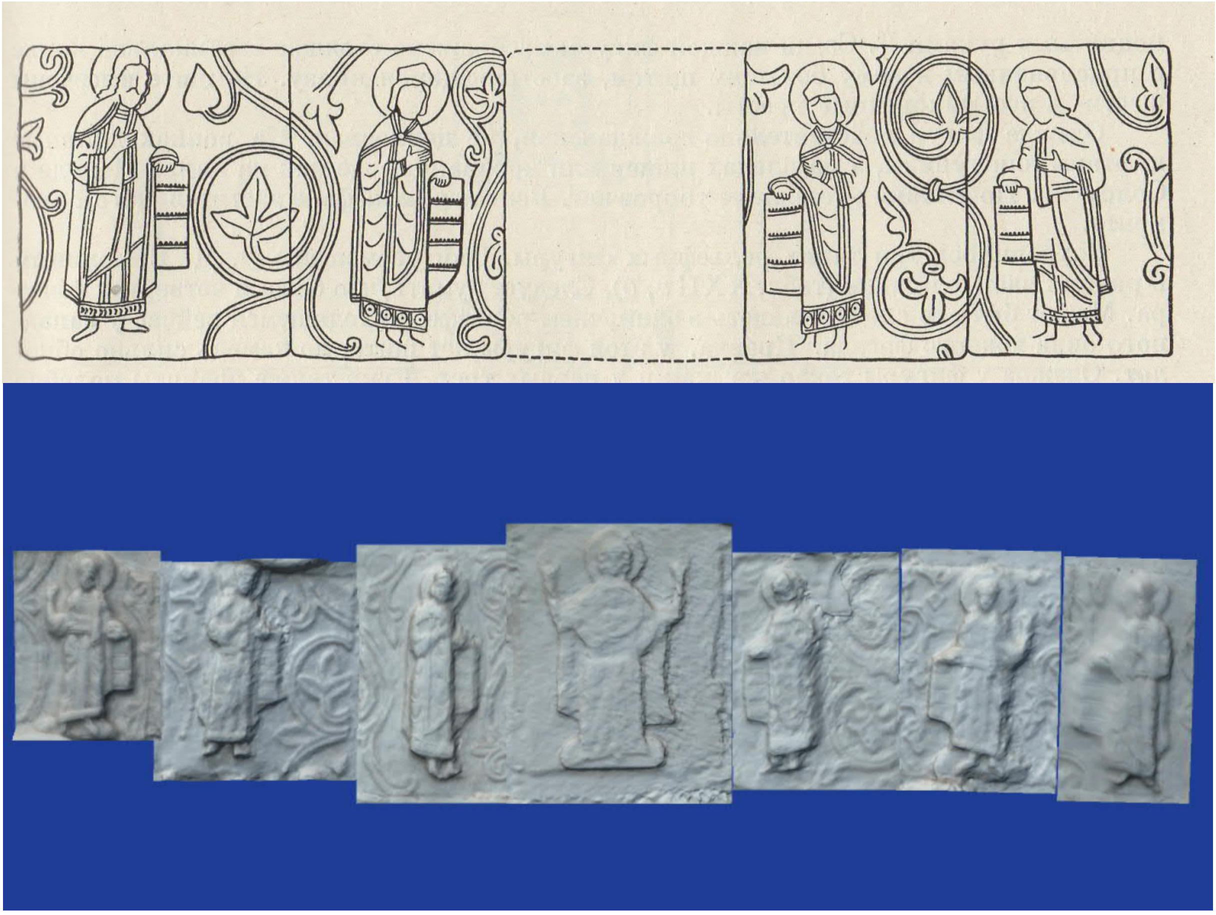

Fig. 8. Vagner's variant of altar images (top) and modern hypotheses (screenshot from Unity3D project, bottom)

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