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)

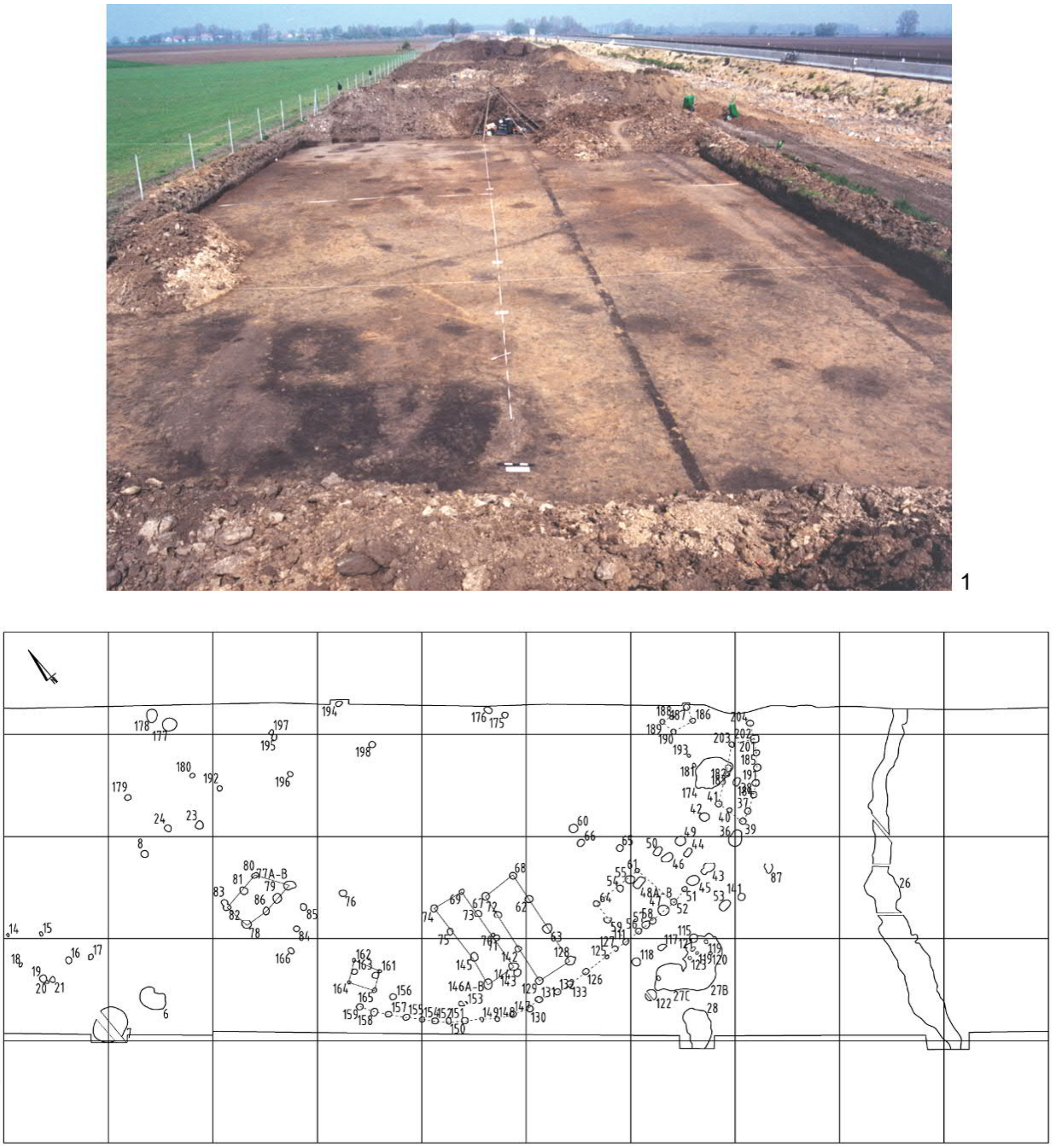

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Fig. 1. The settlement in Stare Śleszów 17: 1) excavations; 2) site plan

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)

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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.

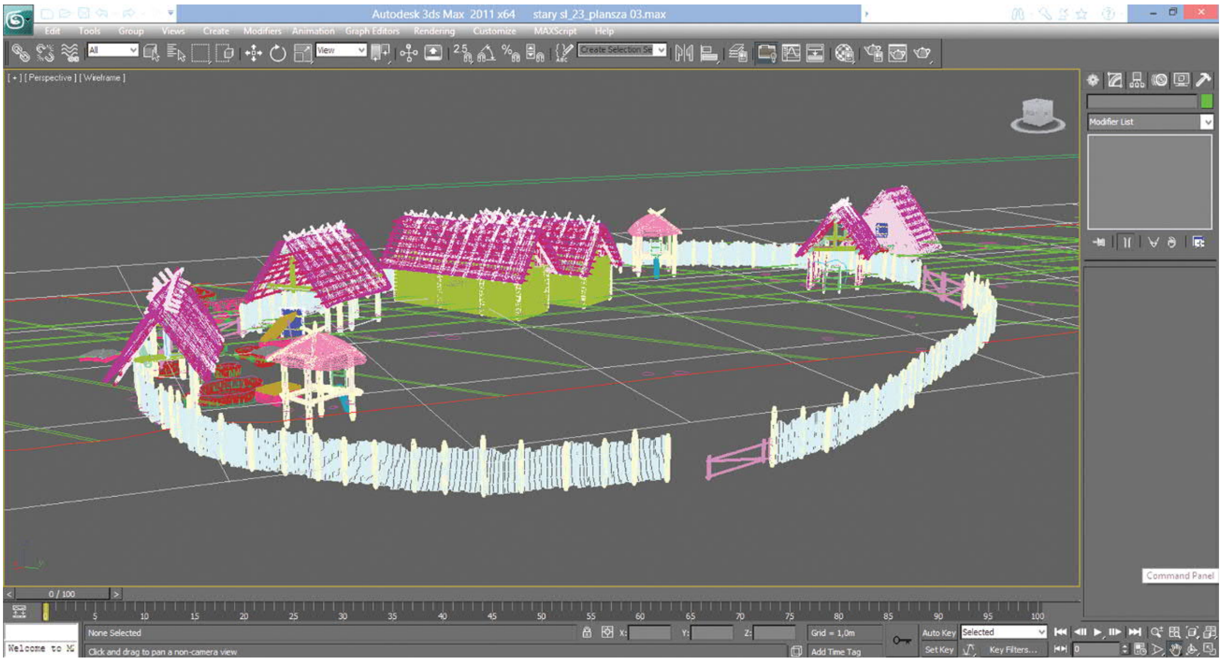


Fig. 3. Three-dimensional model of settlement in Stary Śleszów 17 (by M. Markiewicz)

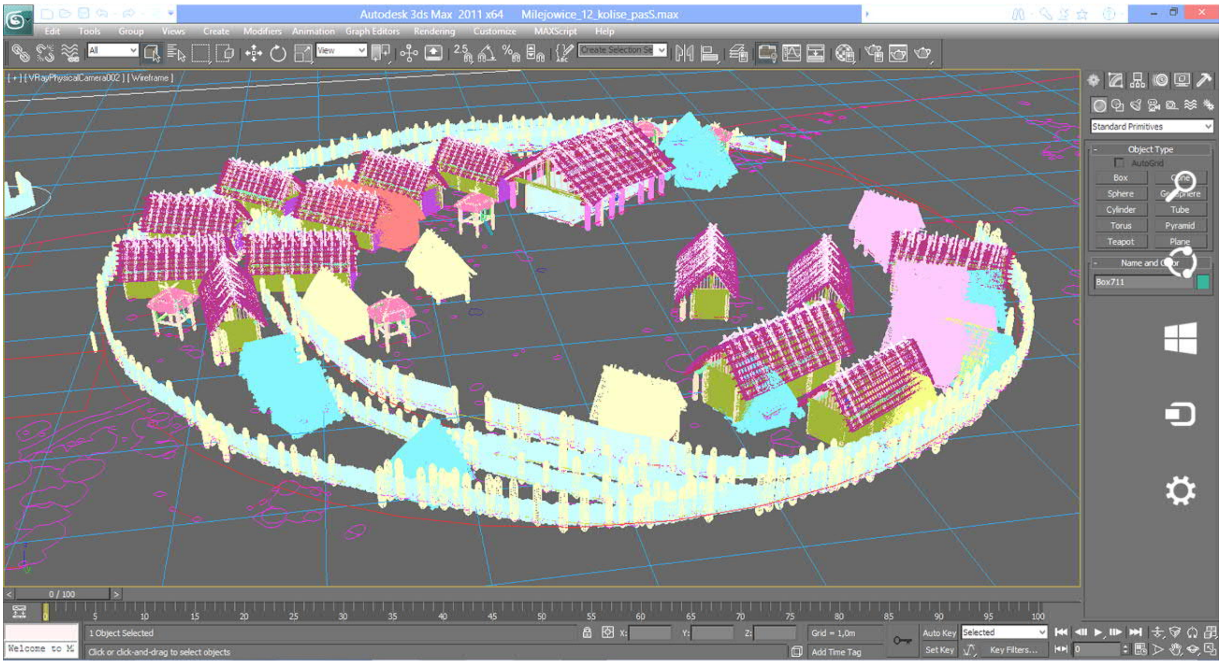


Fig. 4. Three-dimensional model of settlement in Milejowice 19 (by M. Markiewicz)

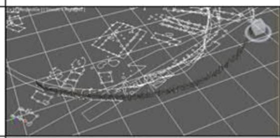
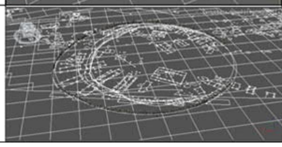
DATA/ DATA	LICZBA GODZIN/ NUMBER OF HOURS	DOKUMENTACJA/ DOCUMENTATION	LITERATURA/ REFERENCES	OPIS CZYNNOŚCI/ DESCRIPTION OF ACTIONS	HIPOTEZY I UWAGI/ HYPOTHESES AND NOTES	PRINT SCREEN	PLIK/FILE
20.06.2018	6	plany: 1: 500, 1:100, 1:20; plan CAD; fotografie; dziennik badań; katalog obiektów	Kopiasz 2004, 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)

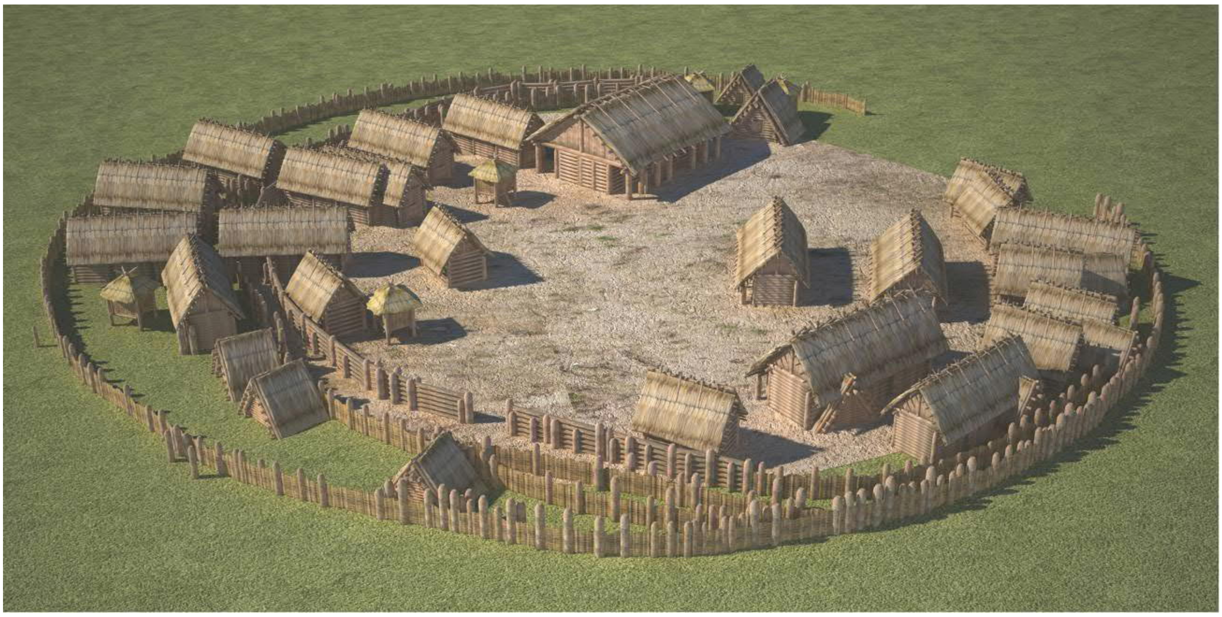


Fig. 8. 3D visualization of a circular structure surrounded with a fence in Milejowice 19: (all objects discovered during excavations). By M. Markiewicz

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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