Visualizing Hypotheses: Practical Handling of Uncertainty in Digital 3D Models

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Discussion and Future Work

Digital 3D reconstructions of cultural artefacts, historical characters and architecture contribute to a better understanding of cultural heritage. In the broad user community, experts from various fields such as architecture, archaeology, art history, paleontology, forensic anthropology, and museology generate 3D reconstructions in order to gain insight into no longer existing evidence. Therefore, such reconstructions are a critical tool for the "translation" of scientific data into visualizations, which make these accessible to the expert community and the general public. It is important to keep in mind that uncertainties are part of nearly all digital 3D models of historical objects due to a lack of sources, ambiguities, interpretation of sources etc. Therefore, strategies have to be found to cope with uncertainties, to visualize them and to communicate them to the audience.

This topic is relevant for many disciplines and seemed particularly appropriate for a multidisciplinary conference like CHNT 24, which took place from 3rd to 6th November 2019 in the Vienna City Hall. To open this topic for discussion in the scientific community the roundtable *Visualizing Hypotheses: Practical Handling of Uncertainty in Digital 3D Models* was conceptualized, which took place on November 4th. Central to the subject of the roundtable were questions like: How to deal with uncertainties in architecture, objects, historic individuals, and fossils? How can hypotheses be visualized in presentations for experts and the general public? Furthermore, the state of the art, and determining factors of a hypothetical visualization were part of the discussion in the roundtable. Four speakers with different scientific backgrounds and from different disciplines—Katharina Ute Mann, Dominik Lengyel, Marcin Szyma, and Oliver Bruderer—were invited to present innovative theories and methods. The present paper serves to reflect on the lectures and in particular on the subsequent discussion.

Short descriptions of presentations

The first presentation was given by Oliver Bruderer, who is a freelance artist and science illustrator with a great expertise in archaeological visualization.[1] Between 2012 and 2016 he was student of the Zurich's University of Applied Sciences (ZHdK) and has received a Bachelor of Arts in Design and Scientific Visualization. He gained practical experience in several projects in Greece, Turkey and Egypt and created numerous archaeological visualizations as part of excavations of the German Archaeological Institute.

In his talk "From the fragment to the big picture. Virtual reconstruction of a fragmented terracotta sculpture" he presented a project led by the German Archaeological Institute's Athens Department in the village Kalapodi in the South Eastern part of Greece. In the focus of the talk was the 3D reconstruction of a large terracotta horse acroterion from the archaic period. The fragments were digitalized using "Structure from Motion" (SfM), generating a 3D model based on multiple photographs. In Cinema 4D Studio (Maxon) the fragments were aligned virtually and missing parts were 3D modelled manually. The aim was to explain visually how the remaining parts form the historic object in conjunction with the reconstructed parts. This was possible in a series of visualizations and especially due to color codes of the different parts.

The second talk presenting a completely different method was given by architect Dominik Lengyel.[2] Since 2006 he is professor of Architecture and Visualization at the Brandenburg Technical University Cottbus-Senftenberg. He conducted numerous 3D projects focusing on the visualization of past architecture, for example TOPOI "The Formation and Transformation of Space and Knowledge in Ancient Civilizations" (2007–2019). In December 2019 his new project titled "Architecture Transformed—Architectural Processes in the Digital Space" started, in cooperation with the Institute of Art History at University Marburg and funded by the German Research Foundation (DFG).

Dominik Lengyel focused on the design of abstraction in his talk "Architectonic design as method of visualizing hypotheses. A direct translation from verbal into visual architecture". He argues that a reconstruction of lost architecture is not possible, as that would mean to construct the building for a second time. Instead, he aims at visualizing lost architecture by including its "architectonic planning and thinking"[3] and he explains that "the design of abstraction is our way of including the visualization of hypotheses and the visualization of the architectural design, that is its original idea."[4] For the visual appearance this means that the architecture is being visualized in grayscales partly as abstract, schematic three dimensional objects and partly rich in architectonic details, depending on the level of uncertainty.

The following talk was held by art historian Marcin Szyma on "A digital reconstruction of a lost work of micro-architecture. Example of the alabaster tomb of St Hyacinth in the Dominican church in Cracow".[5] In his dissertation Marcin Szyma focused on Dominican church and monastery in Kraków in

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[1] For more information see Oliver Bruderer's website: http://oliverbruderer.ch/ (Accessed: 31 March 2020).

[2] For more information see website of the architect's studio: https://www.lengyeltoulouse.com/ (Accessed: 31 March 2020).

[3] Lengyel, Dominik: Architectonic design as method of visualizing hypotheses. A direct translation from verbal into visual architecture, long abstract for CHNT 2019, pp. 1–3, here: p. 3 (unpublished).

[4] Ibid.

[5] For more information see website of the Jagiellonian University: https://ihs.uj.edu.pl/instytut/wykladowcy/szyma (Accessed: 31 March 2020).

the 13th century. He is working at the Institute of Art History at the Jagiellonian University in Kraków. His latest research project "The Architecture and Furnishing of the Dominican Church and Friary Complex in Cracow, from the first half of the 13th c. to the present" is a cooperation with his colleagues and co-authors Jacek Czechowicz (Institute of History of Architecture and Monument Preservation, Faculty of Architecture, Cracow University of Technology), Krzysztof Czyżewski (Wawel Royal Castle, State Art Collection), and professor Marek Walczak (Jagiellonian University in Kraków) and is financed by the Polish National Science Centre.

In his talk Marcin Szyma introduced this joint research project dealing with the digital reconstruction of the tomb of the Dominican St Hyacinth. During the centuries the knowledge about the exact location of the tomb was lost. The project focuses on the evaluation of the past research on the tomb and the testing of hypotheses of its location using digital technologies. A laser scan of the church serves as the basis to identify fragments of the original tomb and to identify possible locations of the tomb. The researchers use colors to differentiate between still existing parts and reconstructed parts to visualize hypotheses.

The last talk was presented by art historian and editor Katharina Ute Mann.[6] She received her binational doctorate with focus on "Polonia – a national allegory as a place of memory in Polish painting of the 19th century" in 2013 at the University of Cologne and the Akademia Ignatianum at Crakow. Currently she is working on her postdoc project "Reenactment of antiquity in form and color by J. J. Winckelmann until today". Her main interests are the reception of antiques, antique painting, and color reconstructions of antique sculptures. Further interests concern art historical places of memory, paintings in Poland, freemasonry, and Palladianism of the 19th century.

In her presentation "Hypothetical reconstruction of antique sculptures in colour" Katharina Ute Mann explained how hypothetic reconstructions of colored antique sculptures are an added value for research. As this group of historic objects is mainly preserved with a white surface and a lack of the original coloring, it is important to indicate the initial appearance of the sculptures and herewith offering insight in the idea of an ancient Zeitgeist. She uses digital technologies to test easily different variants of hypotheses of color schemes. Furthermore, she examines the aesthetic effect and possible functions of the sculptures.

Discussion after the presentations

In the subsequent discussion, which was open to the audience, special aspects and questions that arose from the presentations were reflected. Since the topic of the round table focused on visualization of uncertainties, the aspect of accuracy was a major concern. Oliver Bruderer, for example, made the statement that accuracy is given when hypothetical elements of the reconstruction are indicated. This represents a new perspective on the creation of hypothetical reconstructions in which the concept of accuracy has so far been associated with the selection of a certain type of evidence. The type of evidence, as known so far, will dictate the level of accuracy, as does the availability and quantity of evidence. In this respect, the conclusion that the reconstruction is already accurate due to the marked hypothetical parts represents a new state of knowledge.

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[6] For more information see Katharina Ute Mann's website: https://katharina-ute-mann.jimdofree.com/ (Accessed: 31 March 2020).

Another important point concerned the use of colors in hypothetical reconstructions. In general, colors play an important role in the creation of digital reconstructions. They endow surfaces with properties and thus act as carriers of meaning, because they can be used to visually convey complex information about the model. Methods of representation vary from abstract-conceptual to imitating reality. Katharina Ute Mann, for example, points out the importance of reconstructing ancient sculptures in their original colors. The transience of pigments makes it almost impossible to adequately communicate the ancient idea of colored sculptures, which solidifies the perception of a monochrome-white antiquity: "Not only that the risks will highly create an untrue image of the ancient world, it provokes fundamental changes in the aesthetic perception" (Katharina Ute Mann). This approach is also supported by Franco Niccolucci (2006, p. 22) when he notes in the case of the Mayan city of Calakmul—in what is now Campeche—that the ruins overgrown with vegetation give the visitor a far less clear impression of the former appearance of the city compared to a 3D reconstruction in a realistic style. In the case of Greek sculptures, Katharina Ute Mann also points out other aspects that speak for the reconstruction of past colors. It is known from many ancient cultures that colors convey meaning. Colors therefore have enormous relevance for the interpretation of sculptures and only become "legible" through them, as Vinzenz Brinkmann (2017, p. 27) describes. Another important aspect is that the reconstruction of the former color of the sculptures generates the idea of *Zeitgeist*. This is in strong contrast to the abstract-conceptual use of color, as can be seen in the presentations by Marcin Szyma and Dominik Lengyel. Conceptual surface representations show no realism in the rendering of materials, but apply abstract schemes (such as color scales, grayscale, hatching or specific properties of the reproduced object). In Marcin Szyma's presentation, for example, color was used to mark a status: lost work of the micro architecture was shown in green, while complete sections were represented with realistic colors and textures. On the other hand, Dominik Lengyel's reconstructions are characterized by their lack of color indicating the visualization of an architectural idea instead of real architecture.

Final thoughts

The presentations and the discussion clearly showed the diverse field of possibilities, concepts and methods of how to indicate hypotheses. All of them have their own right to exist, there is no right or wrong, but a multitude of options. The decision of which option to use depends on several aspects like the research question, target group, mode of presentation, state of the examined object, quality and quantity of source material and much more. In special cases it is even a question of philosophy.

The most important result of the discussion was that it is essential to mark hypothetic parts of a 3D reconstruction, and to choose an appropriate stylistic device to indicate the status of uncertainty. In contrast to this an unresolved question still is whether there will be standards or general guidelines to assist research regarding how visualizations of hypotheses can be designed in the future. In order to answer this question, more individual studies are needed, from which standards can be worked out.

Towards Standardization

Nevertheless, preliminary standards can be formulated based on the results of the discussion. These concern in particular the use of color to mark uncertainties. The presentations and subsequent discussion showed that the use of color varies depending on the visualization style. Two main styles can be identified here, Conceptual Style and Realistic Style, which represent diametrically opposed concepts. Reconstructions done in the Conceptual Style do not show any realism in coloring surfaces, but instead assign abstract meaning to them by the use of color scales or grayscale. Color scales are divided into gradations of color tones, each of which is linked to a specific meaning, for example the range between hypothesis and finding (Apollonio, 2016; Maekelberg and Boeykens, 2017; Boeykens, 2011). The viewer of the 3D reconstruction can see at a glance which parts of the objects are hypothetically supplemented in the digital model and which are based on reliable findings, as for example was demonstrated by the presentations of Oliver Bruderer. A primary step toward standardization must be to determine the relation of color and meaning. When using grayscale, for example, standardized gray tones should transport different levels of information. In the case of reconstructions done in the Realistic Style, the use of color is very different from that in the Conceptual Style. Here, colors serve to realistically imitate surface properties. It is therefore not possible to transport abstract information through color. A way to solve this problem could be the use of different levels of transparency. But in this case, too, there is a lack of well determined gradations so far.

As was shown, there are possibilities to establish two completely different styles of visualization of hypotheses in digital 3D models—Conteptual Style and Realistic Style. To fully acknowledge them as standards the community active in 3D reconstruction has to define common guidelines for color and grayscales as well as for levels of transparency. This would be a major step in further establishing 3D reconstructions as research methods and tools, and as a presentation medium in the scientific community.

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