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DIGITAL 2D AND 3D VISUALIZATIONS AS ICONIC EPISTEMOLOGICAL MODELS IN GERMANY

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Abstract

Digital 2D and 3D visualizations play a representative as well as an operative role in the field of investigation of Cultural Heritage. In the beginning, 2D and 3D digital visualizations were mainly used to present results of research projects, but today they are considered more and more as scientific tools to be used in the research process.
Digital 2D and 3D visualizations have the potential to extend the traditional methods of all participating disciplines in the research of Cultural Heritage. Thus, these visualizations could be defined as spatial and object-related iconic epistemological models and media. In these iconic models, the knowledge is collected, merged, and made visible.

Keywords

2D Digital Visualisations, 3D Digital Visualisations, 3D Digital Reconstructions, Digital Iconic Epistemological Models, Digital Cultural Heritage

1. *Approach*

To visualize means making complex contents or facts visible and comprehensible.

Accordingly, visualisations do not use spoken or written words, but imagery as a medium that is deeply anchored in human communication (Heintz & Huber, 2001). Imagery is a universal language that complex issues present in a clear and comprehensible manner (Krause & Reiche, 2015, Pfarr-Harfst & Wefers, 2016).

Researches, artists, and architects were using visualisations to imagine their visions, ideas as well as research results. Visualizations have always been used as a medium in research (epistemological) processes to present, disseminate, and evaluate (Mößner, 2012, p.12).

Polymaths such as Michelangelo or Leonardo da Vinci have already used visualization to present their ideas and visions and to do in-depth studies. Leonardo da Vinci's work includes numerous visualisations of machines or buildings as well as geometric or anatomical studies.

So, to visualize means also to capture the whole world in a simple drawing and uncover all that's hidden.

With the implementation of information and communication technology, a paradigm shift in visualization techniques occurred (Fig. 1). Although computers were more of a digital drawing tool at the beginning, this has changed with the exponential development of technical possibilities (Münster, 2011). The range of technical applications today is enormous. But actually, the term "visualization" includes analogue as well as digital typologies of visualization.

This article focuses on digital 2D and 3D visualizations as a research tool and medium of dissemination in the field of Cultural Heritage and at the crossing point of different scientific disciplines especially architecture, history of architecture and archaeology.

Fig. 1: Digital 3D reconstruction of Crystal Palace (©FG Digitales Gestalten, TU Darmstadt)

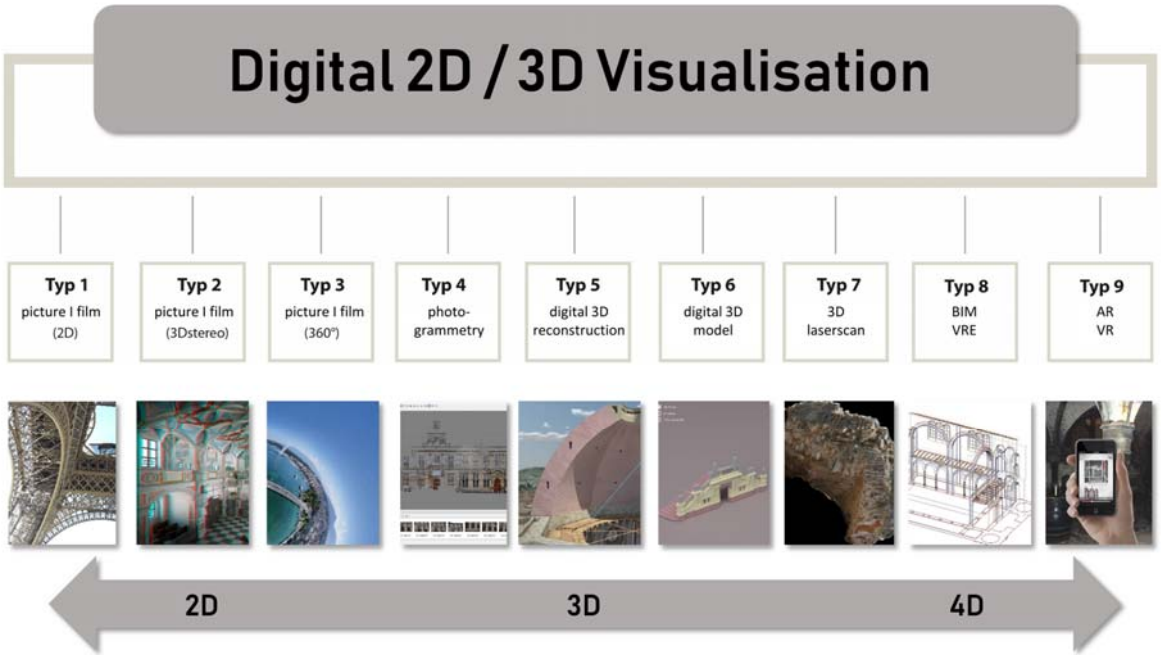

Fig. 2: Typologies of Digital 2D and 3D Visualization

At the beginning, these digital 2D and 3D visualizations were especially used to present results of research projects, but today they become more and more a scientific tool during the research process (Hermon, 2012). All participating disciplines are aware of the potentials of digital 2D and 3D visualization for dissemination as well as research. So, these visualizations play a representative as well as an operative role in the field of investigation of Cultural Heritage.

2. Digital 2D and 3D visualisations

2.1 Typologies

„The power of imagery in conveying information is undeniable, and the digital era has equipped us with new, more powerful tools for visualization" (Knapp, 2019).

The information and communication technologies generate new forms of visualisation techniques as well as new possibilities to visualize. Today, digital visualizations range from simple 2D representations (e.g. computer-generated 2D images, digital 2D maps) to complex, combined 6D applications, that means 3D visualizations (e.g. digital 3D computer models), which are enhanced with the features space, time, information and interaction (Pfarr-Harfst & Wefers, 2016). As mentioned above the term visualisation is a generic one, which also includes various types of digital presentation or application in different dimensions. Nine subclasses of visualisation could be defined within the field of Cultural Heritage (Fig. 2):

Typ 1: film, picture (2D)
Typ 2: film, picture (3Dstereo)
Typ 3: film, picture (360°)
Typ 4: photogrammetry (2,5D/ 3D)
Typ 5: digital 3D reconstruction (3D)
Typ 6: digital 3D model (3D)
Typ 7: 3D laser-scan data (3D)
Typ 8: BIM/ VRE (4D, 5D)
Typ 9: AR/ VR Applications (4D, 5D, 6D)

All these different visualisation typologies and techniques could be further divided into two main groups - born-digital objects (Erway, 2010) and digital reproductions or copies of an original object. While 3D scans as a result of laser-scanning or photogrammetry are digital copies or reproductions, digital 2D-maps, 3D computer models or especially digital 3D reconstructions are examples for born-digital objects.

Within the group of 3D visualisations, it has to be differentiated between so-called hand-made 3D visualisations or 3D visualisations, which are a result of a parametric process. Therefore, the creation process itself is substantial for

understanding the differences between all the visualisation typologies and there use in research and dissemination of Cultural Heritage.

But, the boundaries between these visualisation types are not really fixed, they are often somewhat blurred and all the typologies of digital 2D and 3D visualisation could be combined.

It depends on different influent factors such as project partners, the idea, intension as well as the financial situation of a project which kind of visualisation is finally used.

2.2 Processing and methods

Digital 2D and 3D visualisation are generated by a complex and interdisciplinary process based on facts, interpretations, and heterogeneous sources (Fig. 8). So, such visualisations are a combination of the project background, the contemporary historical and cultural context (*Zeitgeist*), research sources, and the work process. All available information is collected, consolidated, filtered, and put together into a coherent picture (Pfarr-Harfst, 2013). A constant alternation between doing and verifying characterises the whole process. In the end, a digital data set results, which can be processed for different application fields (Pfarr-Harfst & Wefers, 2016).

In the context of Cultural Heritage, a typical creation process of digital 2D and 3D visualisations consists of four main phases framed by the background of the project. The four project phases are "preparation", "data acquisition", "data processing", and "finishing". During the phase of preparation, the background of the project is formed by the intention, underlying visualisation technology, participating disciplines, and should be defined at the very beginning.

The phase of data acquisition includes collecting and evaluating all sources, information, and data.

But, the actual complexity of the task lies in the phase of data processing. During this phase different kind of data, typologies of digital visualisations or heterogeneous sources are combined to a final data set. In the case of digital 2D and 3D visualisations the data processing is mostly a non-automatic, well a handmade process, in which the different work packages are connected by a circulating process (Fig. 3). Besides, a large number of disciplines are now involved in research projects in the field of Cultural Heritage.

In the end, a digital data set is generated, which is the input for the last project phase and the basis for the final form of representation or output

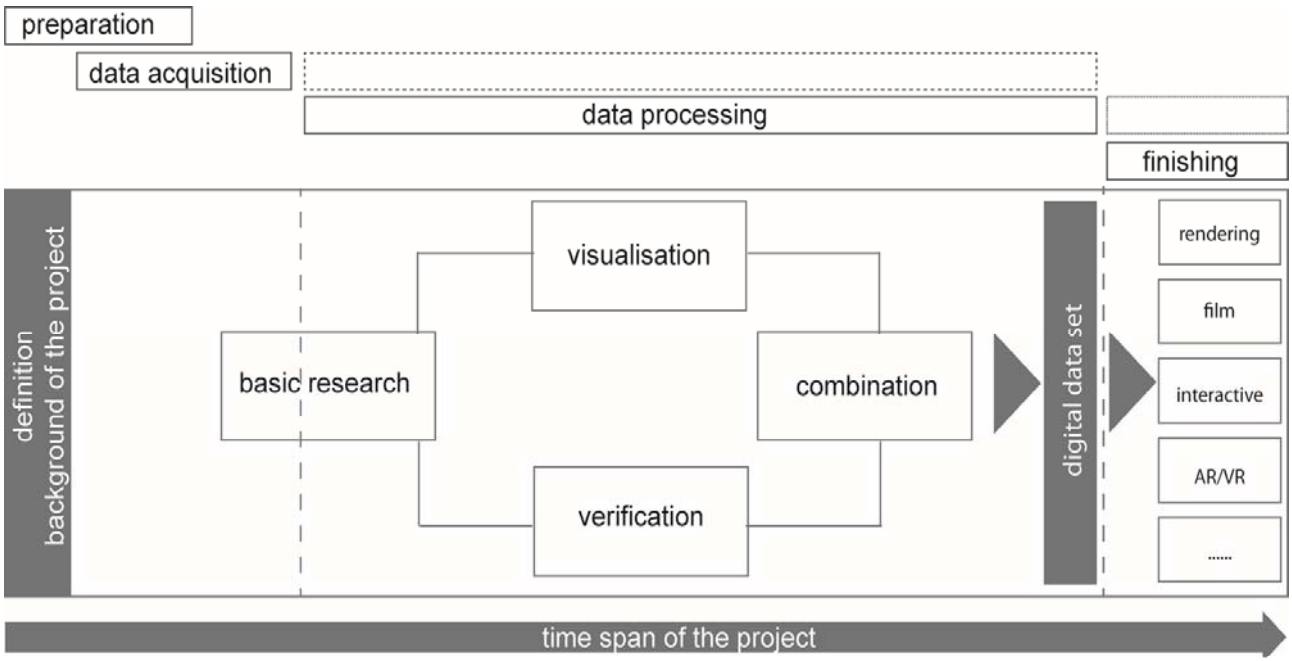

Fig. 3: Creation process of digital 2D and 3D visualisation in Cultural Heritage

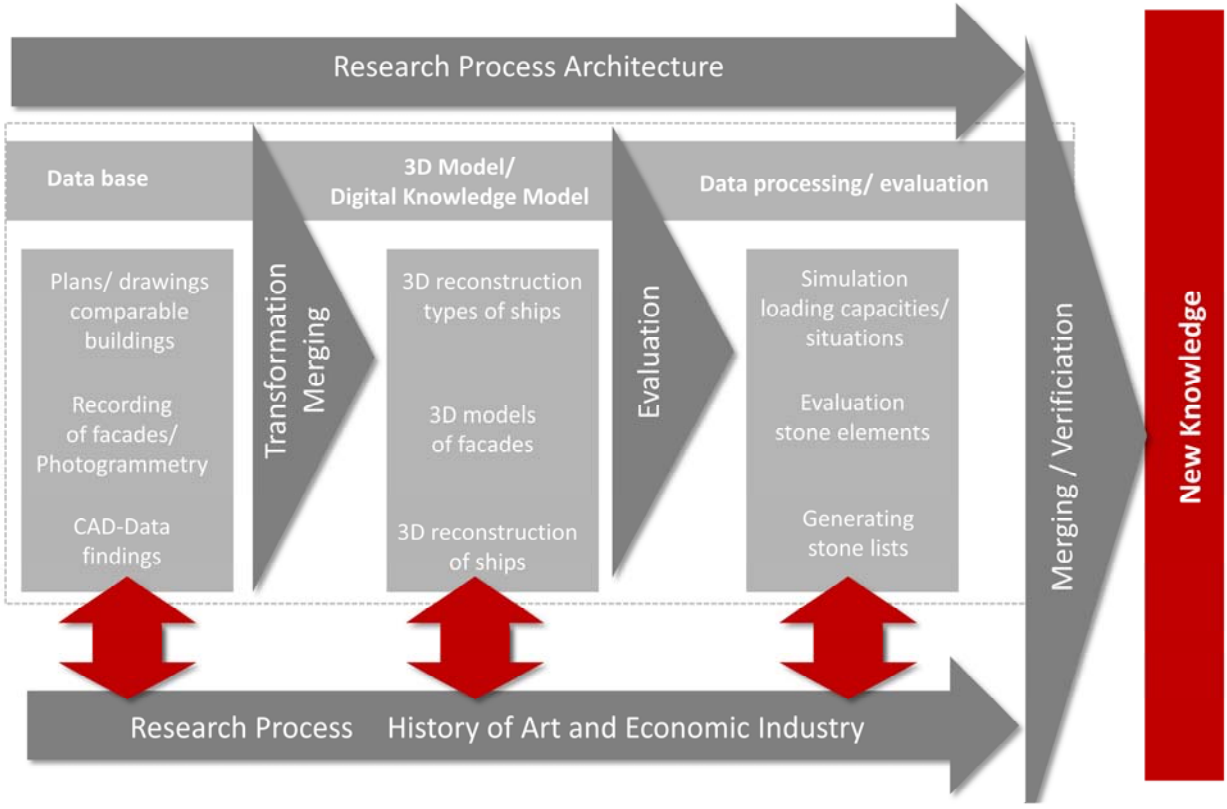

Fig. 4: Research process of the project WESA

formats (Fig. 3) (Pfarr-Harfst, 2015; Pfarr-Harfst & Wefers, 2016).

An example for such a complex process, the combination of different visualization typologies as well as the close cooperation between the involveld disciplines is the research project "WESA - Wesersandstein als globales Kulturgut - Innovation in der Bauwirtschaft und deren weltweite Verbreitung in vorindustrieller Zeit (16.-19. Jahrhundert)".

The objective of the project was to verify a modular construction method and the spreading of Weser Sandstone. An interdisciplinary team of art and economic historians, architects, and computer scientists investigated exemplary objects such as the façade of Leiden City Hall or the Bremer Börse.[1]

In the course of the research project, heterogeneous sources had to be investigated and related to each other. For this objective different 2D and 3D visualisation are combined. During the research process, the visualizations took on an operative as well as the representative role (Fig. 4). On the one hand, they were used as a research tool, which helped to answer specific research questions.

On the other hand, they were also used as a medium for communication between the different disciplines (Backes, Pfarr-Harfst, & Grellert, forthcoming).

The process of this project illustrates, that it is not possible to define a binding method or procedure (e.g. VRE – Virtual Research Environment) for creating digital 2D and 3D visualizations within a project in the field of Cultural Heritage.

As described above, heterogeneous parameters, which differ from project to project, are crucial for the definition of the project background as well as further processing.

Rather, it appears useful to make recommendations for quality assurance. As a hypothesis, it could be possible to summarize all existing methods in one methodology and define best practice examples for specific research issues.

[1]For further information about the project see also: https://www.uni-paderborn.de/forschungsprojekte/wesa/

2.3 Properties and Potentials

Digital 2D and 3D visualizations are characterized through their properties and potentials related to three typical fields of application: research, preservation, and dissemination of knowledge. These fields of application are usually closely linked with one another and there is a complex crosslink between properties, potentials, and the fields of application of digital 2D and 3D visualisations. The properties of digital visualisations generate potentials, which in turn offers a wide range of application options (Grellert, 2007; Pfarr-Harfst, 2013).

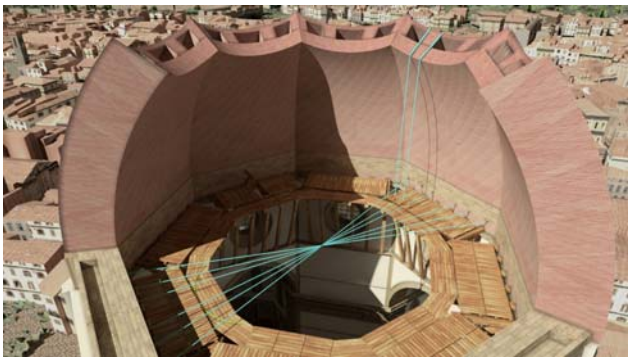

Fig. 5: Digital 3D reconstruction of Florence Cathedral (© FG DDU, TU Darmstadt)

As properties of these visualisations could be defined:

- digitalisation,
- different dimensions,
- imagery.

As a result, these following potentials for their application could be specified:

- Diversity of output forms:

The potentials „diversity of output forms" is based on the property of digitality that allows representing a digital data set in different ways. This ranges from dynamic or static output formats to interactive formats or augmented reality, virtual reality as well as 3D plots.[2]

- Clarification of complex spatial and/or temporal correlations

This potential is based on imagery. Here, as well, many application possibilities have been established. Digital 2D and 3D visualisations can make invisible structures and their context visible as well as understandable (Fig. 6). By means of integration of heterogeneous sources, it could be possible to localise individual finds or objects in buildings and to draw conclusions as to their position, construction, or function (Grellert & Pfarr-Harfst, 2019). This potential is especially typical for 3D visualization.

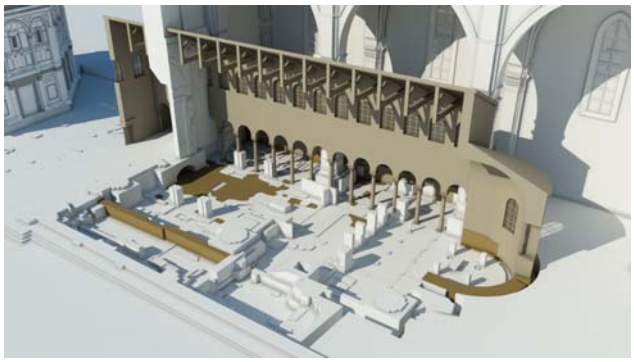

Fig. 6: Digital 3D reconstruction of Florence Cathedral (© FG DDU, TU Darmstadt)

- representation of variants.

Using digital 2D and 3D visualizations, different scientific theses can be compared and evaluated (Fig. 7). They may serve as a scientific tool and communication medium in the epistemological process.

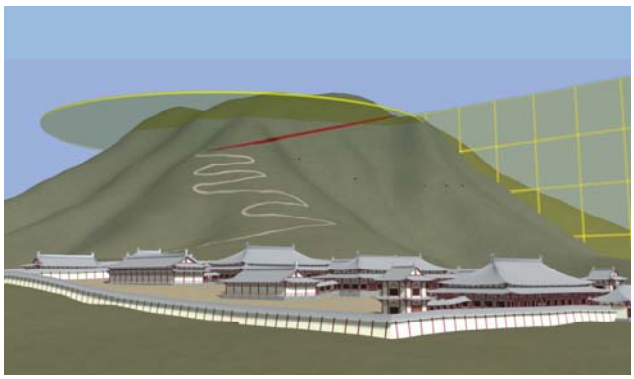

Fig. 7: Digital 3D model for the imperial tomb at Zhaoling, China (© FG DDU, TU Darmstadt)

- Consolidation, generation, verification and dissemination of knowledge.

This potential focuses on the knowledge which is stored in digital 2D and 3D visualisations. Different research results can be merged and verified. In this way, new knowledge could be generated (Fig. 8).

[2] The different forms of representation, such as kind of illustration, output formats as well as presentations formats will be further described in chapter 3.2.

- Communication, interaction, and virtuality.

Digital 2D and 3D visualisations are new forms of research, tools, or mediums of dissemination. In this field, communication and interaction within the virtual space are important features for a vision of future collaboration and dissemination.

Similar to the different types of visualisation the boundaries between the various potentials of digital 2D and 3D visualisations are blurred and could be used for various application possibilities.

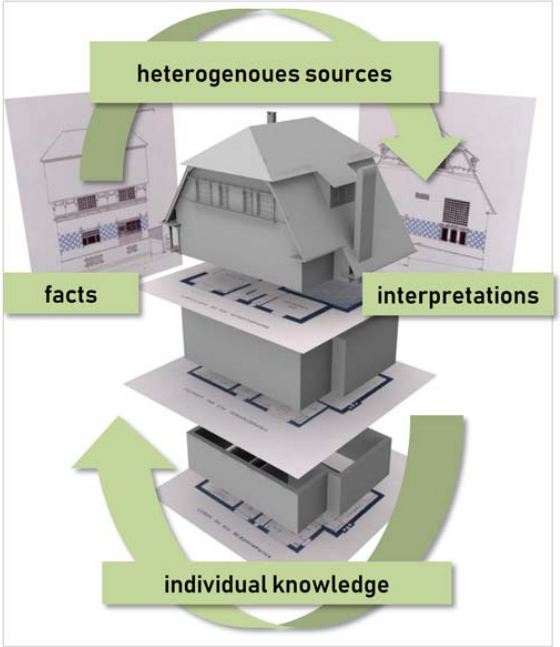

Fig. 8: Merging and interpretation of heterogeneous sources

3. Digital iconic epistemological models

3.1 Definition

Based on their characteristics and diverse potentials digital 2D and 3D visualisations can clarify complex spatial and object-related relationships, extend the traditional methods of the participating disciplines and support interdisciplinary collaboration during the epistemological process (Pfarr-Harfst, 2014).

Thus, these visualisations could be defined as spatial and object-related iconic epistemological models. As defined above in these iconic models the spatial and object-based knowledge is collected, merged, and made visible.[3]

Further, the digital 2D and 3D visualizations become a place of interdisciplinarity, a kind of knowledge repository, and assume an operative role in the epistemological process (Münster, 2014).

In this context, new digital knowledge environments emerge, which become a mirror of previous and future research. In more general terms, these visualizations are not to be understood as simple images, but as visually realized theoretical models or information models.

In the epistemological process, the different forms of representation of these visualizations interact with each other and thus react, apparently, to the goals of the respective research project.[4] Digital 2D and 3D visualization thus become a representative and communication medium of knowledge within this process, a further elaboration of their representative role as a medium of dissemination.

All this also expands the term "image" and the dimensions of the imagery; 2D images of a digital 3D computer model and digital 3D image environments are now being added to the classic imagery. The image in its extended meaning and its various forms of digital representation becomes by the establishment of the digital 2D and 3D visualizations as iconic epistemological models the origin, companion, and representative of knowledge in a research process. The aesthetic moment of the different representations of digital 2D and 3D visualizations in the context of disseminating knowledge is now extended by the epistemic level, which is the level of knowledge.

In digital object-related and spatial iconic epistemological models, data and information are not only merged but also interpreted (Fig. 8) and thus become repositories of knowledge for which three types of knowledge (Fig. 9) can be defined (Pfarr-Harfst, forthcoming; Mahr, 2004).

- Knowledge within epistemological models: This kind of knowledge is stored in digital visualization and generated from the process already described.
- Knowledge around epistemological models: This includes information about the context and background of the project such as project partners, technical systems, intention, and objectives (all of the factors

[3] See also chapter 2.3.

[4] See also chapter 2.2 and the project process of WESA (Fig. 3)

that directly influence the visualization and the end result);
- Knowledge from epistemological models: This includes knowledge that is regenerated from such epistemological models, e.g. in the context of a new research project.

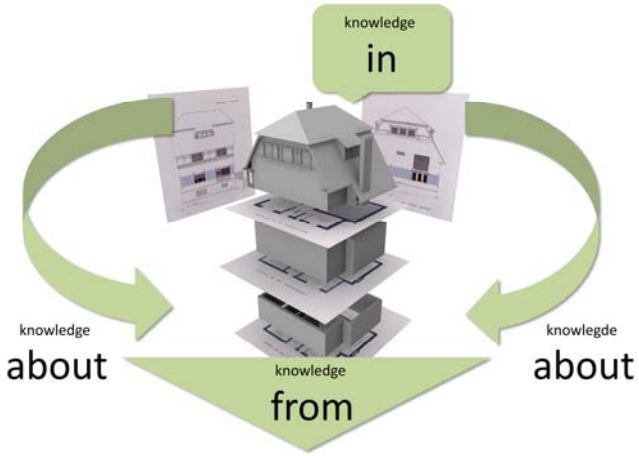

Fig. 9: Three types of knowledge within iconic epistemological models

In summary, it can be concluded that such object-related and spatial iconic epistemological models are more than simple information models.

3.2 Forms of representation

Furthermore, the knowledge stored in such iconic epistemological models need always a form of presentation, which means a medium in or by which it can be presented. Today there is a wide range of such presentation forms, but it is possible to define three categories of representation form for digital 2D and 3D visualizations:

- kind of illustration (e.g. schematic/ explanatory illustration or a realistic image of an object),
- digital output formats (e.g. rendering, 3D image, film, simulation or real-time simulation),
- presentation forms (augmented-reality of virtual-reality-technologies or a combination of different output formats).

The spectrum of the kind of illustration includes schematic or explanatory forms of illustration (Fig. 10) as well as a realistic image of an object, city structures, or single buildings (Fig. 11). Thus, it is possible to illustrate a building in a very simple way, e.g. just as a coloured structure or as a realistic image.

The digital output formats ranges from renderings, 3D images, films, simulations, or real-time simulations.

Augmented reality, virtual reality, or the combination of different output formats could be defined as presentation forms.

All these representation forms may be combined and thus offers great possibilities of representing Cultural Heritage in a digital way.

Fig. 10: Digital 3D reconstruction of Florence Cathedral - schematic kind of illustration (© FG DDU, TU Darmstadt)

Fig. 11: Digital 3D reconstruction of Dresden Castle - realistic kind of illustration (© FG DDU, TU Darmstadt)

3.3 Fields of Applications and role

Digital 2D and 3D visualizations are used at the defined disciplinary crossing point in the fields of research, dissemination, and preservation. The first applications of digital 2D and 3D visualizations were on the representative level as a medium for disseminating in a museum context. Accordingly, the initial theoretical discussion focused primarily on the dissemination and representation of knowledge.

Only in the last decade are the potentials of digital visualizations for researching cultural

heritage and thus as an extension of traditional methods increasingly discussed. They are more and more established in all three defined fields of application as tools in the epistemological process.

Accordingly, visualizations today can play both a representative and operative role in the three defined fields of application

In the field of research, digital 2D and 3D visualizations are used in their operative role as epistemological models to answer various research questions.

Such research questions can include the recording and investigation of no longer visible building or urban structures, the position of findings, the contextualisation of cultural heritage objects, the examination of construction principles and concepts as well as the analysis of construction periods or time layers (Fig. 12).

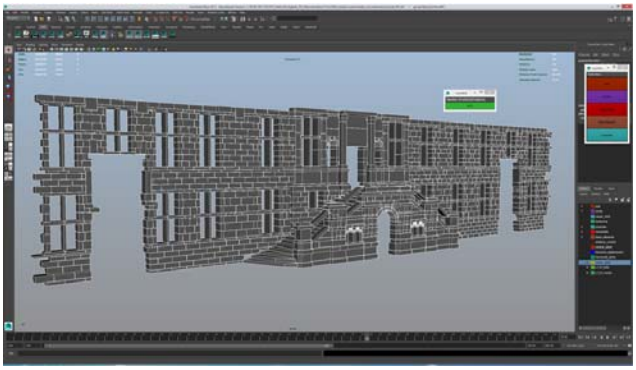

Fig. 12: Structural model of facade of Leiden townhall, project WESA (© FG DDU, TU Darmstadt)

Furthermore, digital 2D and 3D visualizations can also be used as a communication medium in the field of research, where they play a representative role. Which form of representation, for which purpose and at which moment in the epistemological process becomes relevant must always be answered depending on the project objective, research question, and disciplinary participation.

In the application field of dissemination, 2D visualisations, such as animated maps for the representation and transfer of complex spatial and temporal relationships, as well as digital 3D computer models or AR/VR applications are now established (Fig. 13).

Their representative role as a medium of dissemination is particularly prevalent here. The available forms of representation must always be considered in relation to intention, content and context of dissemination.

The documentation of the material and immaterial cultural heritage is the focus of the application field preservation. Here, the forms of presentation range between 2D or 3D digitalised copies of real objects and 2D image and film formats including both roles ─ representative and operative ─.

3.4 Challenges

These application possibilities and potentials of digital 2D and 3D visualisation as iconic epistemological models contrast with numerous challenges.

Despite the ever-increasing use of digital 2D and 3D visualizations in the three-application field, the reflexive moment related to their operative and representative role is missing.

A systematic-structured analysis of the epistemological and communication processes and their role as tools of epistemology and medium of dissemination has not taken place comprehensively, and nor has a theoretical-methodological framework been established.

A project- and technology-based approach is dominating, which is limited to partial issues, single technologies, or the development of technical applications. Often, new technologies are implemented in prototypical applications, which are usually not transferred into a generally valid application (Münster 2014).

This is evident in the missing of standardized definitions of terms and typologies, but also in complex questions, e.g. new forms of imagery. Furthermore, topics such as methodology, epistemological processes, scholarly quality assurance, sustainability, and the field of representation forms for digital 2D and 3D visualizations have not yet been conclusively addressed (Münster, Kurozcynski & Pfarr-Harfst 2015; Arbeitsgruppe Digitale Rekonstruktionen, 2014).

The transfer into standards and guidelines for using digital 2D and 3D visualizations as an epistemological model is also only rudimentarily available. The London Charter (Denard, 2009) and Sevilla Charter (International Forum of Virtual Archaeology, 2014) offer some initial recommendations, but these have only limited practical relevance and are therefore still not being used comprehensively. This is certainly due to the complex creation process of digital 2D and 3D visualizations and the heterogeneity of the disciplines involved as well as their methods and

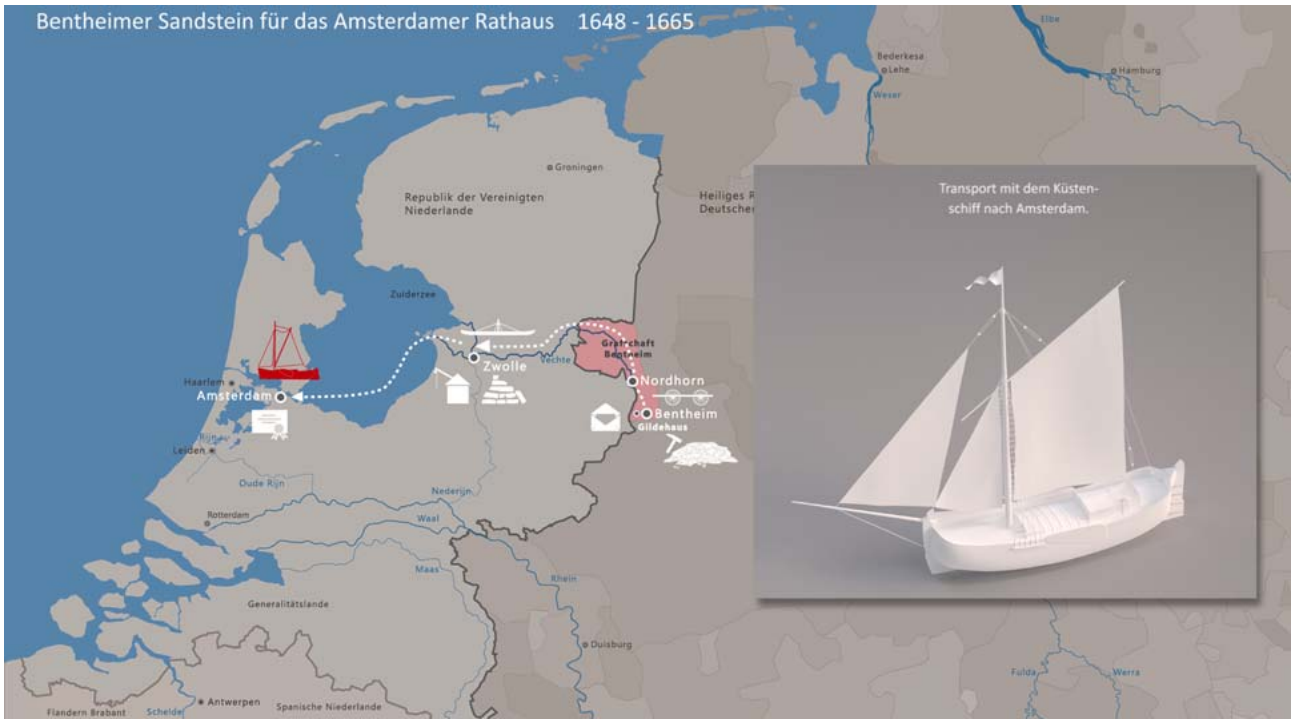

Fig. 13: Animated map of spreading of Bentheimer Sandstone, project WESA (© FG DDU, TU Darmstadt)

research questions. The digital 2D and 3D visualizations, used in the research and dissemination, should be understood as an own typology and focused on as an object of investigation itself, systematically analysed, critically reflected upon, and theoretically framed.

4. Discussion

It has become evident that digital 2D and 3D visualizations have the potential to be used as target-oriented tools into the epistemological processes. However, the implementation of these digital iconic epistemological models is confronted with numerous challenges, which are directly and closely linked to each other. This concerns especially the fundamentals, where it is necessary to develop a methodological and a theoretical framework that includes both the operative and representative role in epistemological processes and dissemination. To now, neither unique basics, rules, standards nor best practice examples are available.

It must be clarified how digital 2D and 3D visualizations can support the epistemological process in the defined field of application depending on the project objective, intention as well as research question. Strategies for the target-oriented use of digital 2D and 3D visualisation in epistemological processes as well as communication strategies in the field of dissemination can only be developed and established on the basis of such preliminary studies can.

4.1 Guidelines and strategies for the epistemological process

Low-level guidelines based on further research of epistemological processes and methods could be the first step to practicable strategies for digital iconic epistemological models (Pfarr-Harfst, 2016).

Such minimal guidelines might be:

- Definition of a binding project framework for all participating disciplines as the basis for the overall project,
- Definition of common project phases and milestones,
- Determination of the 2D and 3D visualizations to be used as well as their technical requirements,
- Definition of binding structures and nomenclatures
- Classification of sources
- Archiving and documentation of sources and project stages

4.2 Communication strategies

The establishment of communication strategies as the first low-level guidelines for the epistemological and dissemination processes is extremely difficult. Currently, there are too many different ideas regarding the types of presentation, output formats, and forms of representation and their use on an operative and representative level. It must be considered that the use of digital 2D and 3D visualizations methods should be guided by the purpose, the intention, and the research questions of the project. Therefore, a critical analysis of all available forms of representation should be carried out at the beginning of the project.

Here such aspects as visual perfection should not be the basis of the decision, but the object, content, and intension of the research project. Particularly in the context of iconic epistemological processes, a simplified representation and presentation should be used.

5. Summary

In summary, digital 2D and 3D visualizations as digital iconic epistemological models have numerous potentials for extending existing research methods in the field of cultural heritage. However, in order to transfer this into uniform epistemological and communication strategies, fundamental analysis of the current status quo must be carried out. This is the basis for identifying the limits of digital 2D and 3D visualizations as iconic epistemological models in the research context as well as in the field of dissemination.

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