Figure 1: "Impossible Construction". 3D Visualization by Sander Münster.

3D Reconstruction Techniques as a Cultural Shift in Art History?

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Abstract: Digital 3D reconstruction methods have been widely applied to support research and the presentation of historical objects since the 1980s. Whereas 3D reconstruction has been incorporated into a multitude of research applications, essential methodological foundations for more widespread utilisation of digital reconstructions have yet to be developed. Against this background, the aim of this article is to consider how the methodology of 3D reconstruction alters research cultures in architectural and art history by exemplifying three problem areas, (1) research functions of 3D reconstructions and their drawback to a current research culture in art history, (2) consequences of cross-disciplinary project-based teamwork within 3D reconstruction projects, and (3) problems and difficulties caused by imagery as primary media for research and communication.

Keywords: architectural history, methodology, digital 3D reconstruction.

1. Introduction

During the past 30 years, technical as well as methodological issues relating to the use of digital technologies in the humanities have been widely researched and discussed, both with regard to prototypic applications and in terms of organisational prospects and infrastructures. Despite the immense efforts expended on the establishment of Information and Communcations Technology (ICT) and, in particular, digital 3D reconstruction technologies—focusing on "the creation of virtual model[s] of historic entities with a need for object-related human interpretation" (Münster, Hegel, and Kröber 2016)—as day-to-day tools for researchers in the humanities, the current situation is still ambiguous. Whereas 3D reconstruction has been incorporated into a multitude of research applications, essential methodological foundations for more widespread utilisation of digital reconstructions have yet to be developed. In this regard, it can be observed that the methodology and utilisation contexts of digital 3D reconstructions of historical entities have been the subject of numerous research studies.[1] While the majority of this research has focused on individual projects, many general methodological issues, such as scientific value added and the discursive potential of the

results, have also been discussed, particularly from the perspective of archaeology and with a view to recording and conserving cultural heritage.[2] So far, however, there is a lack of comparable studies regarding a humanities approach and potentials for the history of art and architecture. This is surprising, since the digital shift, at least according to representatives of digital art history, requires "critical reflection on the methods and practices" of the entire academic discipline of art and architectural history.[3] But what are the reasons for this need for a re-evaluation of the methodology used in art historical research?

The aim of this article is to examine a methodology of digital 3D reconstruction in the context of art and architectural history and to present its significance for research cultures in the history of art and architecture. This will comprise, first of all, a definition of digital 3D reconstruction, followed by a brief review of its development. Considering the question as to how the methodology of 3D reconstruction alters research cultures in architectural and art history, three problem areas will be considered:

- Research context shift: 3D reconstruction not only broadens the spectrum of current research practices and applications in art and architectural history but endorses specific research paradigms, as well as being limited to specific application contexts. What are the research functions of 3D reconstructions? And what are the challenges in relation to current research culture in art history?

- Interdisciplinarity: While art and architectural history are traditionally practiced as individualized research, 3D reconstruction requires cross-disciplinary teamwork as well as organisation in projects. What are the consequences of this paradigm shift for academic culture?

- 3D reconstruction and the visual turn: At present, 3D reconstructions closely relate to an image-based discourse in art and architectural history. This evokes various legitimate concerns about the limitations and biases of images and leads to the question: What problems and difficulties are caused by imagery in these contexts?

2. Definition of digital 3D reconstruction

The central purpose of digital reconstruction is to create a spatial, temporal and semantic virtual model. Essential distinctions are to be drawn between the types of entities under investigation, as to whether they are tangible or intangible entities (such as customs). Furthermore, where working procedures are concerned it is essential to distinguish between a reconstruction of entities that are no longer extant or were never realised (such as designs which were never implemented) and the digitisation of entities that do

exist. Whereas digitisation refers to the technological conversion of an object into a digital representation (for example through semiautomatic modelling using laser scans), a digital reconstruction process requires the human interpretation of data (De Francesco and D'Andrea 2008, p. 231, Münster, Hegel, and Kröber 2016). The creation of a model is then mostly done on the computer using manually controlled modelling software.

It should be borne in mind, of course, that reconstruction is a long-established method that was initially utilized in art history long before the advent of computer-aided visualization techniques. As early as the Renaissance, scholars studied the appearance of the architecture of the past, analyzing it by means of images, among other things, and using it in their creative processes as a model for constructing their own contemporary buildings (Carpo 2001, p. 6). As art history became established as an academic discipline, reconstruction gained new importance, especially with regard to architecture that had been lost; for example, studies were made of the appearance of the Late Antique Basilica of St Peter in Rome, which had been demolished in 1514 (Krautheimer 1937-1977, Arbeiter 1988, Andaloro 2006, pp. 312-468), the early construction phases of the Cathedral of Santiago de Compostela (Hinterkeuser 2003, Horst 2012) or, as a prominent present-day example, the Berlin City Palace (Stadtschloss) (Rettig 2011, Conant 1926). Such traditional reconstructions are prompted by questions as to their original appearance, often posed as issues in the field of archaeology, which cannot be verified through in-situ observation. They may also serve—as in the case of the Berlin City Palace—as the basis for an actual architectural reconstruction.

3. The process of digital 3D reconstruction

The process of digital 3D reconstruction encompasses not only the creation of a virtual model[4] by means of software tools, which is mostly done by specialised modellers, but also the subsequent visualisation, through which the model is rendered into a final presentation format. This process is usually closely accompanied by historical research, through which a sound understanding of the object to be modelled is developed on the basis of sources which provide information from the past (Münster 2013, Münster, Jahn, and Wacker 2017). In view of the resulting division of labour, it is essential to consider the cooperation between those involved as well as the associated aspects of communication and quality management. The entire working process of virtual 3D reconstruction can roughly be divided into the fields of sources, modelling and visualisation (cf. table 1), which may be made up of numerous different steps and tasks and take on different forms.
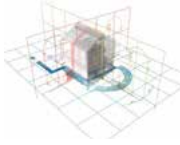
Sources	Modelling	Visualisation
Historical sources such as images: vedute, panoramas etc.; plans; textual sources: construction news, invoices for building work etc.	Semiautomatic model generation	Static images or renderings
	Procedural generators	Animations
	Manual modelling using digital tools	Interactive visualisation (e.g. VR applications or interactive tours)
Contemporary sources such as images: esp. photographs; plans; data: sensory analysis and surveys, topographic reliefs, street maps etc.; texts: scientific papers, esp. studies and architectural history		Data output (e.g. for production or data-based analyses)
Logical sources such as: architectural systems; analogies/ typologies; model logics		

Table 1: Classification of the digital 3D reconstruction process as regards sources, modelling, cooperation and visualisation.

4. A brief genealogy of digital 3D reconstruction[5]

To a greater extent than almost any other aspect of the digital humanities, digital reconstruction is an interdisciplinary field at the interface between research and practical application. Therefore, in addition to questions relating to research and science, there are also numerous applications beyond the academic sphere—for example in the context of teaching, museum displays, virtual tourism, cultural management and entertainment media. Project practice therefore usually addresses issues of both research and communication.

Digital 3D reconstructions have been used in cultural and humanities scholarship for more than 30 years. Furthermore, in the context of architectural history they facilitate research and presentation, and have a growing significance for the long-term preservation, investigation and provision of public access to tangible, intangible and digital cultural heritage and are the subject of broad discourse, particularly from the point of view of archaeology and the recording and preservation of cultural heritage.

A brief outline of the various stages in its development so far will be presented in the following section.

Up to the end of the 1990s, digital models primarily served as substitutes for physical models and graphic representations (Sanders 2012p. 43, Novitski 1998). The first attempts in the sphere of the digital modelling of historical architecture were made in the late 1980s and were at that time an exceptional phenomenon, as in the case of the WINSOM model of the Old Minster in Winchester[6] or the reconstruction of the Abbey of Cluny by Horst Cramer and Manfred Koob (c.f. Cramer and Koob 1993, p. 58-103). In addition to reconstructions of historic, sometimes no longer extant, architecture such as the pioneering reconstruction of the Cathedral of Cluny III (Cramer and Koob 1993), there were also projects in the 1990s which already worked on the visualisation and reconstruction of architecture that had never been constructed—for example, designs associated with the Bauhaus.[7] The reconstruction of destroyed synagogues carried out by Marc Grellert, for example, demonstrated the potential for virtual memorial culture using digital technology (c.f. Grellert 2004). To sum up, it can be stated that in this early phase the spectrum of new opportunities was explored and the applicability of the technology was tested.

As the models were disseminated further and came to be used in research on historic architecture, attention began to be paid, after the turn of the millennium, to the inclusion of digital models in university teaching. For example, as part of the Alten-

berg Cathedral project, experiments were conducted as to how this new technology could be utilised in the lecture theatre.[8] Difficulties arose from the fact that utilisation of the new methods presupposed that architectural historians possess detailed knowledge in the field of computer technology, although this was not included in the curriculum. This then led to the realisation that in order to continue using this technology, changes would be required in the training of art historians (c.f. Günther 2001, pp. 111). In an essay concerning the Altenberg Cathedral project, Stephan Hoppe had already pointed out the need for special academic debate concerning the "interpretative character of these artefacts [here referring to digital reconstructions]" (Hoppe 2001bp. 99). In particular as regards source evaluation, the creation of digital models requires considerable preliminary work and scientific analysis, which also involves other genres such as photography and drawings, as well as written sources.

Starting points for methodological criticism are provided by the field of Visual Studies, where crucial observations have been made (c.f. Schmidt-Funke 2010, Roeck 2004, Burke 2003, Haskell 1995) but in which the digital 3D reconstruction of historic architecture and its representation have been dealt with only peripherally or not at all, this task having been left almost entirely to the field of architectural research.[9] At the start of the new millennium, the widespread application of digital reconstruction in

the academic sphere necessitated the development of exemplary standards as well as the establishment of a scientific community devoted specifically to this field (c.f. Frings 2001, Münster and Ioannides 2015). An overview of the possible means of communicating the scientific content of the models was presented in a talk by Ute Verstegen in 2007, in which various projects and communication systems were presented and analysed (Verstegen 2007).

An elaborate and comprehensive analysis of the current state of research in the *Digital Humanities*, which also includes the use of 3D technologies for reconstructing historic entities, was conducted by the EPOCH network project completed in 2008, which drew on numerous leading European institutions and protagonists to demonstrate not only the status quo but also the development potentials and research desiderata.[10] The results of this analysis were reflected not least in the subsequent funding priorities concerning 3D applications in the field of *Digital Humanities*, which focus primarily on aspects such as the minimisation of costs and the ease of use of software tools for creating digital 3D reconstructions (c.f. European Commission 2011). As the possibilities offered by this technology have grown, the fields of application for digital models have also continued to expand. Rather than serving merely as a substitute for established media, their role as a presentation medium (c.f. Greengrass and Hughes 2008) and in the field of academic research and

education, has continued to develop (c.f. Favro 2006). However, the visualisation of historical entities continues to be its principal function.

Since about 2010 a new phase in the development of digital reconstruction has been underway. This is characterised not only by efforts towards methodological validation but also its broad incorporation into relevant disciplines and, not least, its integration into academic teaching. With regard to achieving wide impact, the Framework Programme for the Humanities, Cultural and Social Sciences established by the German Federal Ministry for Education and Research (BMBF) in 2013, for example, aims to "create the prerequisites for networking between disciplines in virtual research environments and to significantly expand the research area, access to digital sources and their availability." (Bundesministerium für Bildung und Forschung 2014).

4. Digital techniques as a cultural shift in humanities scholarship?

Against this background, a major task is to enrich the currently highly application-oriented process of using digital reconstruction tools for visual

humanities research purposes by providing it with a critically reflected methodological basis and by anchoring it in academic culture.

What is the purpose of digital research methods in the context of architectural and art history? According to Heusinger, computers support art history scholarship in the following ways:

- Data collection, e.g. through digitisation;

- Data retrieval from database records with the transfer of knowledge;

- Examining visual humanities questions, e.g. a composition of complex figurative paintings;

- Reconstructing, simulating, and producing objects; and

- Administering and organizing people and objects.[11]

A general question asked concerning the use of digital methods in these contexts is whether computing methods lead to novel, ground-breaking research questions, approaches, or insights. Studies on this topic have been—from the perspective of architectural and art history—primarily conducted with regard to research contexts (i.e. Günther 2001), research objects (i.e. Bentkowska-Kafel, Cashen, and Gardiner 2006), or by distinguishing phases of the research process (i.e. Kohle 2013). On a more general level, scientific activity and the "production" of insights have been widely discussed in sociology and

philosophy (i.e. Fleck 1980, Peirce 1931, Latour and Woolgar 1986, Knorr-Cetina 2002). While the use of information and communication technologies in most cases simply extends non-digital possibilities, and general research applications in terms of approaches used and research questions asked are mostly similar to those of the pre-digital age, the qualities and quantities as well as workflows have changed dramatically against the background of digital development (e.g. Moretti 2007). Taking several well-grounded systematisation approaches (Pfarr-Harfst 2013, Günther 2001, Drucker 2013, 9) into consideration, added value for research methodology in the visual humanities that can be provided by digital methods may include:

- Scaling: The use of computing may ease the collection, management, and analysis of large-scale data and information sets.

- Editability: Digital work can be edited, transferred and duplicated, and later modifications to a research paper, for example, are possible.

- Information combination: The combination of information from different fields of knowledge may generate new insights.

- Pattern recognition and application: Patterns or systematics can be used to generate hypotheses or to reduce the complexity of large-scale data (c.f. Spence 2001).

Against the background of the discrepancy between the new technical opportunities that exist and the methodology and issues, which largely remain the same as in the past, there is a need for debate in three areas in particular: of special significance are the fields of the research environment, interdisciplinary collaboration and the critical evaluation of sources and of the models being created; in short, the content-related, methodological and procedural consequences that arise from 3D reconstruction.

5. Research contexts for 3D reconstruction in art history?

The research that underpins digital reconstruction must be recorded and systematized (Pfarr-Harfst 2013). Current approaches are mostly based on historical exemplification—as in the case of the historical method proposed in Section 2—aiming to distinguish several research contexts (e.g. Günther 2001). On a more general level, the process of research and the insights to be gained are widely discussed in sociology and philosophy (e.g. Fleck 1980, Peirce 1931, Latour and Woolgar 1986, Knorr-Cetina 2002). The question of the purpose and function of individual research approaches, such as the process of digital 3D reconstruction, also requires inves-

tigation. Although there are various other research approaches—such as numerical techniques like the finite element method (FEM) or computational fluid dynamics (CFD)—visualisation is the most common way to present digital 3D reconstruction. According to Ware, visualisation can support research and understanding in five ways (Ware 2004, cited according to Frischer and Dakouri-Hild 2008, pp. V):

- It may facilitate the cognition of large amounts of data.

- It can promote the perception of unanticipated emergent properties.

- It sometimes highlights problems in data quality.

- It clarifies the relationships between large- and small-scale features.

- It helps in the formulation of hypotheses.

Taking this generic scheme and several approaches to grounded systematisation (Pfarr-Harfst 2013, Günther 2001) into consideration, the authors would like to propose a preliminary typology of research approaches, as shown in table 2, which distinguishes between research objects and objectives of relevant research.

Research approaches	Source	Object	System
Documentation (e.g. compilation and recording of knowledge)	X		
Data quality assessment (e.g. consistency or contingency of sources)	X		
Visualisation (e.g. investigation of shape or appearance)		X	
Creative process (e.g. planning or construction)		X	
Conceptualisation and contextualisation (e.g. typologies, functional segments, archetypical elements, provenance)	X	X	X
Numerical analysis (e.g. structural analysis, lighting)		X	
Hypothetic simulation (e.g. of hypothetic objects deriving from an architectural system)			X

Table 2: Research approaches in digital reconstruction.

Use of 3D digital reconstruction to research a certain historic entity or its parts is common. Three-dimensional reconstruction is also employed to investigate and evaluate sources. Sometimes the focus of research is not on a specific object but rather schemes and systems, for example, an investigation concerning the Vitruvian system of architectural orders. Against this background, 3D reconstruction methods are often employed to derive archetypes or specific features (Ling, Ruoming, and Keqin 2007).

The question concerning the "original" being reconstructed is closely related. The "original" can be a certain intention (e.g. of a builder), a specific source, or a historic object. Research objectives are:

- Documentation: In the case of digital 3D reconstruction, the objectives of a virtual model are primarily to assort, store, and compile spatial-related knowledge (c.f. Sachse 2002). For example, the 3D model of the Domus Severiana provided a spatial map and therefore the possibility to geo-reference sources (Wulf and Riedel 2006).

- Data quality assessment: Contextualisation and assessment of the consistency of sources is a focus of research. For example, digital reconstruction of content depicted in drawings or paintings can be used to test perspective features or consistency (c.f. Carrozzino et al. 2014). Discrepancies between ground plans and elevations or vedute are revealed through this.

- Visualisation: The most common way to visualise is to formulate a hypothesis regarding the shape, properties and appearance of a certain historic object. Concerning this aspect, digital reconstruction allows the non-invasive application and testing of alterations or restoration.[12]

- Process investigation: Another type is research into historical preparation processes (e.g. planning or construction processes employed by craftsmen, sequence of planning phases, modifications, interruptions).

- Conceptualisation: A major question for underlying concepts and intentions, such as structuring concepts (c.f. Saft and Kaliske 2012), refers to functions of certain parts of an object (e.g. rooms, figuration or proportions).[13]

- Contextualisation: Other objectives concern the contextualisation of objects (e.g. geo-location, relationship to other objects, visual axes) and the identification of archetypal characteristics. This may refer, for example, to the craftsman's specifications and typologies, as well as comparison of iconographical concepts. Contextualisation may lead to a research interest in sources and specific objects, as well as systems (Kohle 2013).

- Numerical analysis and simulation: For gaining dynamic data from models there is the possibility of simulating different kinds of forces and processes. Structural analysis is one area of application (c.f. Mele, De Luca, and Giordano 2003), but there is also the

possibility of examining the function of certain parts of a building or of path networks in combination with the surroundings.[14]

- Hypothetical simulations[15]: Different usages are possible without making a reference to specific historic entities, for example, the exploration of hypothetically possible objects which derive from a certain architectural order and the related (hypothetical) limits and boundaries of this system (Wagener, Seitz, and Havemann 2016, Ling, Ruoming, and Keqin 2007).

Unlike research findings presented in the form of texts, 3D models require extremely complex information about the appearance of a historical entity in order to produce a concise reproduction. As Fish points out, "CAD systems [...] 'make it hard to be vague'" (Fish 1994, p. 502, cited after Sachse 2002, p. 63)—a statement that undoubtedly applies to all current 3D modelling techniques. 3D reconstruction also forces its creators to answer questions which existing sources leave open, a requirement that contrasts with current scientific procedural models in the humanities and cultural studies, where the attempt to "show how it actually was" (von Ranke 1824, p. 1) has usually given way to centring on a problem (Wengenroth 1998, p. 5). Correspondingly, historical research in the context of 3D reconstructions consists not only of the interpretation and evaluation of existing sources; rather, in order to produce a coherent model, hypotheses have to be developed that go beyond a

"dialogue with the sources themselves" (Wengenroth 1998, p. 4). Possible gaps in the sources must be documented, identified and made traceable as such. Any supplementary conclusions made by analogy also have to be accompanied by a valid explanation. Only through such supplementary information can an architectural model, which at first glance seems to be self-explanatory, be open to scientific scrutiny and thus be comparable. This subsequently gives rise to the question of whether 3D reconstructions represent a step backwards in the evolution of historical scholarship.

6. Interdisciplinarity of 3D reconstruction?

In digital reconstructions, information technologies serve to produce virtual historical models. In addition to computer science as the "tool provider", content-related perspectives acquired from archaeology and the history of culture, art and architecture, architectural research and museum studies, are also involved. Owing to the highly specialised nature of the tools, a model is usually created not by the persons responsible for the content themselves, but rather—in the context of an interdisciplinary project—by modellers who come from the disciplines of computer science, architecture, geosciences and engineering as well as design.

The reasons for this lie not least with the process of modelling, which is mostly based closely on the procedural models used in these disciplines. Whereas VR, animation and CAD tools are used to reproduce the form of an object and its surface in varying degrees of quality, BIM and GIS tools serve to systematise and process object volumes and object relationships. What is more, numerical simulation tools such as CFD, FEM or lighting analyses in turn require the use of specialised procedures during model construction and analysis.

On this basis, the work of the art historian is fundamentally different from that of the architect, who is able to undertake his or her construction activities without an additional modeller. Further contrasts derive from their respective approaches; the architect is primarily concerned with their own design process, whereas the art historian seeks to reproduce historical reality as faithfully as possible. Consequently, art historians are required to work strictly on the basis of proven sources, whereas the architect can more freely assimilate various influences. This brief comparison alone makes it clear that the modelling focus in these different disciplines is highly divergent.

Many challenges for 3D reconstruction projects are connected to a lack of interdisciplinary understanding. Intensive support by images during a reconstruction process could foster interdisciplinary communication, in particular, and could be used as a "cre-oles" (Styhre 2010) for the exchange and sharing of mental models. For that, it is necessary to synchronise terminologies or to employ "common grounds" like symbols, colours or tags. Such decisions and tasks should be started at an early project stage and should be controlled and adapted throughout the entire project process. Ideally, such visual coding schemes would be a mental model shared by all members of the project team and would be documented and based on either extant coding schemes, e.g. from engineering, or would use "natural" codings like physical analogies or concrete depictions (Tversky 2002) to make these issues recognisable at later times or even accessible for later works. But in all cases images would only support communication and, especially for complex tasks and interdisciplinary exchange, personal contact would be more useful than communicating information over long distances.

Resulting challenges include questions regarding the access to and evaluation of models and images, as well as references between reconstruction and (explainable) fundamental knowledge such as sources.

A specific challenge is presented by the division of labour that we see in a typical project. It is evident from published project reports that interpretative 3D reconstruction projects are almost always interdisciplinary in nature, with the working teams mostly only coming together temporarily, unlike the situation in

companies (Nausner 2006: 57 f.). The tasks are usually divided between historical research and the creation of the model. Where working procedures are concerned, the division of labour between the historical researchers or historians on the one hand, and the creators of the digital model on the other, are so strong that it is possible to speak of "human-human-machine communication". In this context, the organisation of work, the distribution of tasks, and effective communication are therefore correspondingly important.

7. Images and 3D reconstruction

In art history, in particular, visual media are an important foundation for working, even beyond the predominant genre of painting. Every object, whether it is a painting, sculpture or building, can be investigated anywhere thanks to various visual representations. Regardless of whether a building still exists, images and plans are essential basic sources. In connection with this, a number of basic working techniques can be derived. In addition to the critical evaluation of relevant sources and critical thought, which are required in particular for reconstruction where comparison with the original is not possible, this includes visual comparisons and reference to comparable existing entities.

Generally, research about the use of images is nothing new and has taken

place in relation to their utilisation in various contexts like engineering, design or architecture, or in a scientific and research context (Gooding 2004). Regarding the quality of images as visual signs, there are many possible dimensions, such as similarities to a depicted object, visual styles or creation processes (Bresciani 2013).

The use of images in a research-related context would not only include functions such as memorisation, documentation or communication within projects or of results. Such images would also be important for problem solving and related activities, such as information sorting and solution negotiation (Sachse 2002). Particularly the humanities, and especially archaeology, art history, and history of architecture, deal with historic images as sources of reconstruction. Types of sources and their relevance for 3D reconstruction are a prominent topic in academic literature (Hermon 2008, Remondino et al. 2009). However, these are not new phenomena: especially with regard to the reconstruction of architecture— the most prominent type of entity reconstructed in such projects (Münster 2016)—communication via images has had a long tradition since early modern times (Carpo 2001).

Results of 3D reconstruction are mostly static images, animations, or even interactive visualisations like computer games. An approach to their classification is delivered in the engagement taxonomy developed by Grissom et al., which differentiates

six degrees of interactivity for such visual output (Grissom, McNally, and M. F. & Naps 2003). Closely related are questions concerning information communicated by such visualisations. Such aspects are theorised in several approaches such as visual decision making (Nutt and Wilson 2010) or visual learning theories (Gagné, Briggs, and Wagner 1988, Pahl and Ahlborn 1998, Schwan and Buder 2006).

Unlike in text-based disciplines, knowledge is mainly gained by the creation of a virtual model and its digital, in most cases, visual demonstration in the case of digital reconstruction. Moreover, contributions of different authors and a multiplicity of intuitive decisions are included in such media which are based on know-how (Münster and Prechtel 2014). So far, neither an academic culture nor mechanisms have not been established for making digital models and related images scientifically linkable and discussable. This also includes the capacity to quote parts or areas in models and images, and the modification of such media by others. In addition to a number of technical requirements, the development of approaches for the documentation of processes and their results, and the capacity of making a model logically transparent, are derived (Hoppe 2001a, Günther 2001).

8. Conclusion

Are digital 3D reconstruction techniques causing a cultural shift in art history? Whereas 3D reconstructions have now become established and recognised at least as a method of illustration beyond representation-related discourse (Sanders 2012: 43), its full recognition as a method of investigating historical facts and circumstances has still not been achieved. This implies questions of its added value for research and the discursive potential of such projects. It is urgent that these questions should be clarified, not least in view of the fact that methods of 3D reconstruction are not only being increasingly used in various ways in art history, but also because the sheer quantity and public use of tools and the liberalised distribution options available via the Internet (c.f. Münster 2011) are increasingly beyond the control of traditional professional discourse.

Our article demonstrates, on the one hand, that the use of methods of 3D reconstruction is bringing about a number of fundamental changes as compared with previous practice in the field of art history. This includes not only the quantitative and qualitative expansion of opportunities for researching architectural objects and sources but also, particularly against the background of numerical simulation and pattern recognition, the development of a large number of approaches to research that were previously not feasible. On the other hand, there are problems associated with the primarily visual investigation of (virtual) reproduced objects and—from the point of view of art and

architectural history—the non-transparent design processes, the need for interdisciplinary cooperation and as a holistic representation of the past, what might be considered a "retrograde step" in the disciplinary evolution in art history.

In light of the fact that art and architectural history have developed an elaborate approach to such problems as part of an intensive, centuries-long discourse, it would indeed appear that the need for art historians to learn about computer graphics and 3D modelling is urgently necessary. Looking to the future, two particular challenges are evident. On the one hand, 3D reconstruction for the purpose of research in the history of art and architecture needs to be validated and developed in respect to methodology. What are also of essential importance are impulses from the history of art and visual studies, as well as validation by them as regards research culture and technology, in order to overcome the current methodological deficiencies in digital reconstruction for the purpose of investigating historical architecture.

Notes

[1] Among the historical disciplines utilizing these techniques, archaeology in particular, as well as—to a lesser extent—art and architectural history, play a leading role, both methodologically and conceptually. That it is now firmly academically established is evidenced, not least in archaeology, by a considerable number of established and regular conferences and workshops as well as periodicals. An analysis relating to this is to be found in (Münster, Köhler, and Hoppe 2015).

[2] Examples of such status reports include the final reports of the EPOCH projects and the European Commission's ICT Status Report, which provide a general description of a research landscape and current discourses: (Arnold and Geser 2008, European Commission 2011). An example of an extensive compendium dealing with aspects of scientific digitization and the 3D reconstruction of historical buildings is (Frischer 2008)

[3] International workshop "Digitale Kunstgeschichte: Herausforderungen und Perspektiven", 2014 (http://sik-isea.ch/Portals/0/docs/Z%C3%BCrcher%20Erkl%C3%A4rung%20zur%20digitalen%20Kunstgeschichte%202014.pdf; accessed 15.09.2015).

[4] Aspects of the exemplary character of the model have been discussed at length on various occasions. For an overview of approaches taken by various disciplines and in the history of ideas, see: (Sachse 2002, FN 16), specifically in relation to 3D reconstruction: (Pfarr-Harfst 2016).

[5] The doctoral thesis by Heike Messemer, which is currently nearing completion, aims to develop a genealogy of digital 3D reconstruction. Research findings from this project are presented in (Messemer 2016).

[6] Project period: 1984-1986 - Lit.: (Burridge et al. 1989).

[7] An overview of reconstruction projects from the point of view of art history in German-speaking Europe: List of digital models of historic architecture (http://www.digitale-kunstgeschichte.de/wiki/Liste_digitaler_Modelle_historischer_Architektur; accessed on 15.09.2015). As a compendium of international projects, particularly from the perspective of archaeology up to the mid-1990s: (Forte and Siliotti 1997)

[8] Project period: 1997-1999; persons responsible: Doberkat, Ernst-Erich and Nußbaum, Norbert. Literature: (Hoppe and Scheer 1999)

[9] On this see also (Ackerman 2002) and (Recht 1995). In keeping with the title, (Linfert 1931, S. 133-246) are still also used.

[10] (Arnold and Geser 2008). One specific focus of

this investigation was the positioning of *Digital Heritage*—however, the results represent a state of research which, for the majority of the aspects dealt with, can be generalized as applying to all fields of 3D reconstruction in the historical disciplines.

[11] Based on: (Heusinger 1989). Particularly cited after: (Bentkowska-Kafel 2013, p. 6). Moreover, a range of media and applications in digital humanities scholarship, particularly digital art history, is presented in: (Bentkowska-Kafel, Cashen, and Gardiner 2006).

[12] For example, removing alterations of stat-ues introduced in the course of an earlier con-servation treatment. Discussed in (Fontana et al.); For the restoration of fragmented objects, see (Arbace et al. 2013).

[13] The approaches followed until now concentrated mainly on analyzing architectural plans. Discussed in (Wiemer 2005, Masini et al. 2004).

[14] For example creating simulations of ancient ventilation systems. See (Balocco and Grazzini 2009).

[15] A definition of "simulation": (Hinterwaldner 2010, pp. 31-41 & 68-69).

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