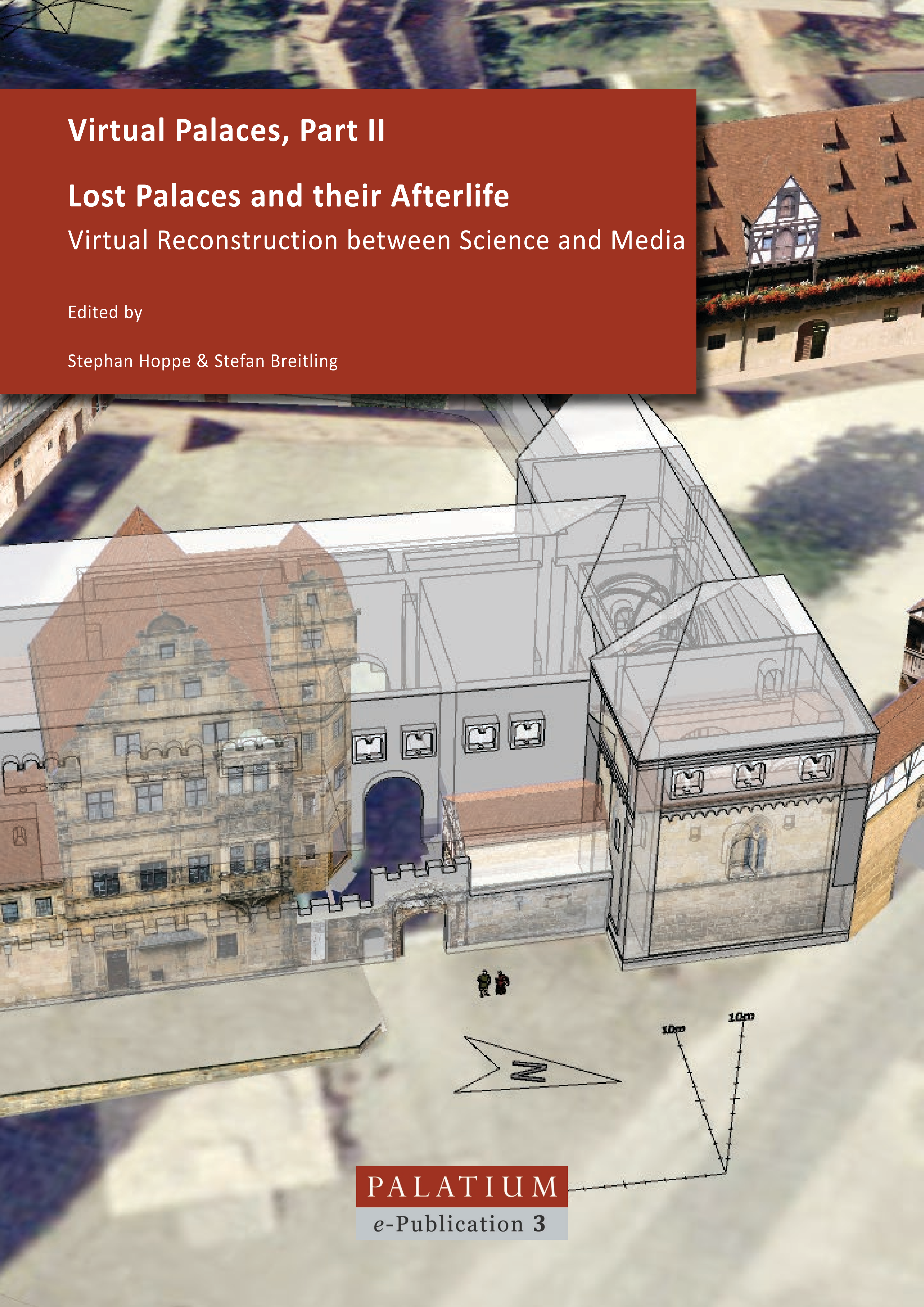
Virtual Palaces, Part II

Lost Palaces and their Afterlife

Virtual Reconstruction between Science and Media

Edited by

Stephan Hoppe & Stefan Breitling



PALATIUM
e-Publication 3

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With the assistance of
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Cover image: Bamberg, Alte Hofhaltung at around 1300. Overlay of the medieval palace with the photorealistic model of the surrounding area, as it is today. Breitling/Buba/Fuhrmann/Uni Bamberg 2012, building research by Burandt 1998, nowadays city model by Carlo Schramm, Stadtplanungsamt Bamberg 2012.

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Acknowledgements

Stephan Hoppe (Ludwig-Maximilians-Universität München, Germany)

Stefan Breitling (Otto-Friedrich-Universität Bamberg, Germany)

The essays published here were originally contributions to a workshop, which took place at the Ludwig-Maximilians-Universität in Munich, 13-14 April 2012. The editors would like to thank, first and foremost, all those presenting at the conference and, in particular, the authors of the chapters in this volume.

While some papers seemed better placed in other publications, others could not be incorporated in this volume for reasons of time. Among the papers that had to remain unpublished are: Hubertus Günther: 'Research and Teaching by Means of Computer Visualization'; Leonhard Helten, Anke Neugebauer, Johanna Reetz: 'Chronotopos Wittenberg. Reviewing Town, Church and Palace'; Marco Antonio Ricci: 'Al-Khawarnaq: Topos and Reconstruction of a Lost Early Islamic Palace'; Laura Fernandez-Gonzalez: 'Re-creating Ephemeral Architecture: the Lisbon Festival of 1581'; Sabine Frommel, Giancarlo De Leo: 'The Projects of Pierre Lescot for the Reconstruction of the Western Aisle of the Louvre'; Gergely Buzás, József Laszlovsky: 'The Virtual Reconstruction of the Medieval Royal Palace at Visegrád (Hungary) as a Case Study'; José Luis Sancho: 'Virtual Models of the Spanish Habsburg Royal Palaces: Dealing with Patrimonio Nacional Research and Public'. All these papers made a magnificent contribution to the Munich symposium.

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The editors, München and Bamberg, February 2016

Preface

Krista De Jonge, PALATIUM Chair (KU Leuven – University of Leuven, Belgium)

Founded in 2010 and financed by the European Science Foundation, the PALATIUM research networking programme aimed at creating a common forum for research on the late medieval and early modern European court residence or palace *(palatium)* in a multi- and trans-disciplinary perspective (www.courtresidences.eu). In the broad and varied field of court studies, PALATIUM's focus on the court residence stands out as a main defining characteristic, distinguishing it clearly from similar initiatives in Europe. Fourteen research institutions from eleven European countries supported this initiative during its five-year run. Thanks are due here to all member organisations who stood behind this 'network funded by a consortium' and to its 'parent company', the European Science Foundation; but also to KU Leuven – University of Leuven on the one hand and the Ludwig-Maximilians-Universität München on the other, the hosts of the double event, which is reflected in the volumes no. 2 and 3 of the PALATIUM *e*-Publications.

Through its methodological workshops, PALATIUM meant to attract specialists in court studies (historians, art historians) ready to work with architectural historians in an interdisciplinary perspective, and to help develop new methods or tools, with the specific aim of developing user-friendly ways of presenting the research in this field to the larger community.

The collection of essays presented in the volumes no. 2 and 3 of the PALATIUM *e*-Publications, resulting from the Leuven meeting of 18-19 November 2011 and the Munich meeting of 13-14 April 2012, is dedicated to the reconstruction of the palace as virtual heritage. Over the past decades, digital reconstructions have proven their usefulness in visualizing palaces but also in clarifying data and research results (e.g. construction phases, ceremonial use). PALATIUM's interest focused on the methodological implications of these increasingly sophisticated tools, i.e. the interface where architectural history and digital technique must meet and interact. Within this perspective, Part I, *Digitizing and Modelling Palaces* (Leuven) focused on the digital recording and virtual modelling of historic buildings in their actual state, and the related methodological problems, while Part II, *Lost Palaces and their Afterlife. Virtual Reconstruction between Science and Media* (Munich) focused on virtual reconstructions of 'lost' buildings and their role in research on court residences. Neither of these volumes has any pretensions to covering the whole subject, but rather aims at raising awareness – on the historian of art and architecture's side – of the added value such digital tools can bring to the research on residences, and at setting out the necessary boundary markers – on the digital expert's side – guaranteeing the scientific usefulness of digital reconstruction. As the second and third volumes in PALATIUM's series of *e*-publications, we hope that they will easily reach their audience.

Virtual Palaces, Digital Images – an Introduction

Stephan Hoppe (Ludwig-Maximilians-Universität München, Germany)

Stefan Breitling (Otto-Friedrich-Universität Bamberg, Germany)

This collection of essays deals with digital scale models of historical, courtly architecture from the medieval and early modern periods. Digital models of historical architecture, often called virtual models or CAD models to distinguish them from 'real' haptic models, are a relatively new medium of the digital age. Their use has started to become more widespread in the late 1980s. The digital or virtual architectural model in general is based on a complex, processed dataset and, therefore, a highly technological phenomenon, while the digital data at hand are almost invariably used to create digital images and their variants, such as films, panoramas or interactive representations. These up-to-date digital images often resemble, in style and content, older, analogically produced images. Their fundamental visual aspects may be described and studied with the methods of art history, of visual studies (Bildwissenschaften) and of the social sciences. Of course, other research approaches are conceivable as well but could not be discussed here.

There is a close and productive interrelation between 'real' historical palatial architectures, which is at the centre of our attention as objects of such virtual models in this volume, and the ideas that we have about them, which are circulating in diverse groups of discourse. When the images, for example in the case of digital models, gain comprehensive qualities and even start to depict spatial entities one may justifiably refer to the new digital images as virtual palaces.

Palaces or other princely architecture play an important role for the expression of national or regional identity; they offer condensed images of specific societies, analysed, for example by Norbert Elias, under the category of courtly society. Elias early on referred to architecture as an indicator of social structures ('Wohnverhältnisse als Anzeiger gesellschaftlicher Strukturen').[1] Palaces are, therefore, as important for the perception and the appropriation of the early modern period as the architecture of the great cathedrals is for the Middle Ages. A good deal of the historical and cultural impact of these palaces and residences is virtual even without any digital processing – in the sense, that we have to imagine long-lost situations and parts of the architecture as well as the every-day-life, the ceremonies and the other processes and events that once took place in and around them.[2] Often the building fabric of these palaces has undergone serious change over the centuries. Therefore, from a historical point of view we are always dealing with reconstructions.

In addition, the way we look at these monuments as part of our built heritage, the aspects we are interested in and the connotations we add to these remains of courtly and aristocratic culture deeply depend on a visual construction of history. The way these sites are represented to the public is often highly professional and complex. The architecture, the collections and exhibitions on display, the stories told, attest to the importance of our imagination when dealing with the palace-theme. There we find a broad range of interpretations and historical reconstructions, starting from different backgrounds and diverse political intentions together with a multitude of techniques and skills to visualize an intended message that is well worth investigating. Both virtuality and visuality have long played an important role in the presentation and reception of courtly architecture and palaces in particular.

As a result of specific technological innovations and medial traditions, digital models of historical architecture first materialised in the 1980s. They complemented older architectural reconstructions and images, in particular the haptic models made from wood or other such materials whose particular history may be traced back to the 14th century:[3] it is likely that they will increasingly replace them altogether. As soon as the digital or virtual model attempts to reconstruct a no longer existing architectural reality, it becomes the virtual alternative to a potential physical reconstruction.[4]

Nonetheless, unlike physical reconstructions, their virtual counterparts also play an increasingly important role as tools for the more scientific exploration of this type of architecture. In particular, as concerns the creation and communication of scholarly results, 'non-built' digital kinds of media, such as reconstruction drawings, maps, diagrams, photographs and film play an important part. Whether it concerns the reconstruction of a historical status quo, the explanation of diverse contexts of usage, the tracing of parent networks or communication with a range of clients, such research by necessity relies on virtual reconstructions as visual representations of diverse lost realities. Thus, our present-day notion and understanding of courtly architecture is greatly influenced by such digital images and, more specifically by virtual scale models.

The range of scale models of historical architecture has considerably expanded with digital techniques. Technology is increasingly used for the review of theoretical models, for the purpose of representation and for the documentation of research processes. In particular the digital integration of entire academic workflows, of databases, thematic maps, GIS techniques, CAD drawings and videos has a high potential for innovation.[5] While not all of these depictions may be described as images per se, images have gradually started to play a more central role.

At this point, it seems opportune to introduce the peculiarities, constituent processes and scenarios of the reception, and advancement of the recent visual medium of the digital architectural model in its relationship to in-depth, theoretical research. Several disciplines, such as art history, visual studies, or sociology of knowledge may be considered, since they develop historical as well as systematic research objectives and analyse phenomena in contexts that go well beyond the representation of isolated cases.

Such a *modus operandi* gives rise to questions about the qualities, possibilities and limitations of different techniques and strategies of virtual reconstruction. The use of digital models brings new perspectives for the sciences as well as for the medial presentation of research results. However, what is the state of the art in building digital models of historical palaces? How deliberately do researchers, model-builders, and recipients use the new techniques and the dazzling possibilities of diverse modes and styles? What does the virtual picture of these palaces look like? Do these images conform to a particular style and does this style follow examples developed by other media?

Even though we are used to overpowering visual impact from the film, advertising and gaming industry,[6] the scholarly and lay audience's skills of evaluating or analysing 3D-media have not grown in tandem. Therefore, a gap exists between the growing role and professionalization of the visual reconstruction of the historical and of the theoretical background. Although media theory is dealing with this issue, users from historical fields of research have not yet addressed much of its scientific influence.

Those historical buildings, whose digital models have been chosen as objects of investigation in this volume fall mainly in the areas of the research of art history, building research (Bauforschung), medieval archaeology and cultural studies. It is important to emphasize this fact, since at this moment studies and surveys of earlier, pre-medieval cultures do not only provide the majority of digital reconstructions, but also reflect on and publish research about the new medium most assiduously.[7] The essay by Sander Münster in this collection, for example, illustrates this circumstance very clearly. A number of analytical positions that strive for an interdisciplinary character in this volume are also relevant to this publication.[8]

Within the scope of the more recent architectural history the digital scale model as a new genre of both data and image creation has long been rather neglected from a theoretical perspective. With the exception of the presentation of single projects, for example those put into a wider context in Heike Messemer's essay in this volume, the proceedings 'Der Modelle Tugend', compiled by Marcus Frings (Darmstadt, 2001), deserve a special mention.[9] Although by digital standards, much time has passed since 2001, we must urgently turn to the historical and theoretical aspects of the new digital visual medium – including the areas of medieval and early modern art history. In particular, the approaches employed by visual studies (Bildwissenschaften), which are deeply ingrained in German-language art history, may develop further in this field.

The essays published in this volume, originally were contributions to a workshop entitled 'Lost Palaces and their Afterlife – Virtual Reconstruction between Science and Media', which took place at the Ludwig-Maximilians-Universität in Munich, 13 to 14 April 2012. This event formed the second part of a series of conferences on 'Virtual Palaces', organised by PALATIUM, an international scholarly network funded by the ESF and dedicated research on 'Court Residences as Places of Exchange in Late Medieval and Early Modern Europe (1400-1700)'. In 2011, the first workshop in Leuven in 2011 dealt with modes of recording and surveying existing palaces, preserved interiors or ruins and explored issues of maintenance as well as the development of digital techniques in this field.[10]

Organized jointly by the Institute for Art History at the Ludwig-Maximilians-Universität München (Stephan Hoppe) and by the Institute of Archaeology, Cultural Heritage and Art History at the Otto-Friedrich-Universität Bamberg (Stefan Breitling), the workshop in Munich focused on the virtual reconstruction of lost palaces and its theoretical impact. Digital architectural models and virtual reconstructions have long been integrated into the day-to-day academic work at both institutions: they are used for teaching as well as constitute a tool for research and an object of research.

As a main result of the conference, it has become clear that by now digital reconstructions have turned into a complex medium of historical reconstruction not to be disregarded by researchers in art history and architectural history. The quality and range of the models and projects presented are impressive, as is the diversity of the approaches employed by the models'-builders. The scholarly impact of digital models has to be planned very carefully: therefore the theoretical basis and its parameters need to be queried for each single case study. In particular, the following issues are crucial contributions to the debate: What is the best way to provide the spectator with a convincing and intriguing picture of past eras? Or should they be allowed to reach their own conclusions by a method that provides them with the necessary information and leads them to the right questions? Equally important are queries regarding data maintenance, regarding access to the database through supporting systems and regarding the accessibility of a digital model to later change.

The first essay in this volume aims to give an introductory historical survey, charting the early stages of the use of digital architectural models in art history since the 1980s. This chapter was added to the conference presentations since it provides a systematic gateway to the general topic. It is based on Heike Messemer's doctoral research on the subject of the genesis and typology of digital models of historical architecture during the post-classical period. Such an overview of early types, uses and target groups of digital models in the context of sacred and courtly architecture attests to its importance and originality in the history of art.

The contribution by Michael Rykl likewise approaches the subject of digital architectural models of medieval castles from a historical vantage point. By using Czech examples, he demonstrates how the experience made in traditional reconstructions of castles and élite dwellings in the field of building archaeology could be transferred to the visual conception of digital images.

In the third essay, Sander Münster and Thomas Köhler discuss diverse virtual reconstruction projects and aim for a synthesis by way of sociological analysis. The contribution raises the issue of the academic audience of virtual architectural models. Statistics based on an in-depth analysis of literary sources including websites and e-publications on current projects underpin their research. In Italy and Spain, for instance, e-publications discussing virtual models of palace architecture document a substantial part of research, whereas most of the northern European countries continue with traditional publications in the field of history. North of the Alps, e-publications concerned with virtual modelling remain largely for a matter for computing specialists and aim for completely different target groups.

The following chapter composed by the architects Dominik Lengyel and Catherine Toulouse explores the formal and visual conditions for building of scientific digital reconstructions. One of the main issues that determine the scientific model as both a database and a digital image is the issue of how to handle sharpness and uncertainty of historical evidence and how to display it in the digital reconstruction. Depending on the concentration of archaeological or historical knowledge, every model includes parts defined by diverse levels of historical and architectural sharpness. The thoughtfully prepared and communicated principles, forming the basis of the high-end Pergamon model, allow the audience to take part in the archaeological discussion on the reconstruction of this famous place. This example made it particularly obvious that there is no 'pure' model making. Since the style of the large digital Pergamon model is strongly influenced by Neoclassicism, it not only provides scientific data but also information on the traditions of classical archaeology and architectural theory.

The colourful sketches and visualizations of the Cambodian residential metropolis of Angkor Thom by Tom Chandler and Martin Polkinghorne on the contrary attempt to show the rich tapestry of daily life and thereby represent the wider cultural context. The study presents a very interesting way of dealing with uncertainty by revealing the sources and the reconstruction process for every detail. It offers divers solutions for the reconstruction of highly uncertain parts, so that one may follow the implications of a range of assumptions. The cartoon-like drawings help the viewer to understand them as a reconstruction in progress and to reserve their judgement. Digital technology makes it possible to provide simultaneous access to all of these layers and thus to create an interactive communicative basis.

The essay by Marc Grellert and Franziska Haas demonstrates the value of digital models when employed as knowledge transfer strategy for lost building structures by using new digital models as well as haptic models of 17th century Dresden and her castle (Residenzschloss). The main result of the work so far, includes a rapid prototyping plaster print of the castle and its spacious environs as well as a virtual tour through the streets, courtyards and selected interiors of the former residential palace in 1678. In addition, the Dresden example demonstrates the potential of the rapid prototyping models for research and as possible strategies when dealing with 'gaps' in the available information.

The specialized discipline of building archaeology (Bauforschung) has a rich tradition of model making. Linked to the field of conservation, it is both descriptive and analytic, since this kind of models tries to show fragmentary evidence in its spatial context and thus to explain complex architectural situations. In addition to the Czech examples given by Michael Rykl, the chapter written by Olaf Wagener, Christian Seitz and Sven Havemann and the one composed by Stefan Breitling, Martin Buba and Jan Fuhrmann show additional examples of and distinctive approaches to making historical building fabric readable. Therefore, virtual models are a useful tool for non-destructive archaeological research as well as for defining the historical impact and cultural wealth of architectural remains and sites. Here, we also find digital modelling used as an interactive tool for scientific research. With the availability of airborne landscape scans, also the scenic context of architecture may be modelled. This innovative technique leads to the analysis of historical views from and to castles or to the reconstruction of the reach of medieval firearms on the basis of the charted impact of missiles. It also serves as an appropriate kind of research tool to locate and geo-reference historical evidence as well as displaced or lost objects in architectural and landscape models.

Virtual reconstructions can be understood and implemented as spaces of specialized knowledge. As sets of data they may contain single pieces of information such as construction data, source extracts, surveys and documentation embedded in a multidimensional context. Visually presented space is thus enriched by a range of meta-information and thereby acts as a metaphor for the spatially-organized 'interface', which refers to an essential scientific framework. Wherever rich literary sources are available, the digital model may adapt to diverse realities described rather than keep the same focus throughout.

Ever since the start of a research project on the 16th-century inventory of the 5th Duque of Bragança, D. Teodósio I, drawn up for the palace of Vila Viçosa in Portugal, the spatial dimension has played a central role. While the palace has repeatedly undergone structural changes up to the present day, the documentation under investigation in combination with an interpretation of the building existing today, one may virtually rebuild its architecture as an unique approach to the history of this ducal house. The essay by Ana Catarina G. Lopes reports on how the research team develops their project, for example the registration of all the metric and geometric information as well as architectural and topographical surveys, including photogrammetry. The architectural model is fundamental for the acquisition of a tool that allows for the testing and for the clarification of the types, forms, functions and geometries of this building complex, while also permitting to launch interpretations related to the artistic domain and functional programme. Finally, it ought to help with the evaluation of the possible impact of subsequent construction phases.

For certain kinds of scientific usage the image as the result of research is less interesting than the principles, on which the reconstruction is based, such as the overlaying historical evidence, historical plans, analogies and the probability of a plan. The visualization of Rubens's Palace projects for the 17th-century Antwerp Nieuwstadt by Piet Lombaerde and Marc Muylle is based on such principles. This radical approach to the creative use of diverse and experimental digital models for architectural research is of great value for educational use. To place Italian-style palaces virtually in the northern city and to compare their plans and architectural features to the neighbouring buildings from different periods clarifies the reasons for a regional building traditions and helps with its evaluation. If students study the history of architecture in this way, they practise their skills in architectural drawing as well as in 3D-construction while also getting a deeper insight in the constrictions set by climate and geomorphology and in the principles of historic architecture and town planning at the same time.

The interactive open-source internet-based project by Alexandra Gago da Câmara, Helena Murteira and Paulo Rodrigues regarding the reconstruction of pre-earthquake Lisbon is based on the painstaking collection of every detail known about the almost entirely devastated older town. Therefore, the virtual model helps at the same time to cope with the shock brought by catastrophe and to fill the gaps in the memorial culture of a community.

The close link between research and model-making allows for the prudent organization and management of larger reconstruction projects such as the Dresden Zwinger project presented by Peter Heinrich Jahn, Markus Wacker and Dirk Welich. The model making actually provides deep insights in the historical and topographical situation of past times, but also into the skills and methods of the builders of this past. In this way, the building of a model turns into a process parallel to the complex planning of a masterpiece of 18th-century architecture.

The essays of this volume make evident the strong relations between the new digital models and more traditional forms of visualizations, such as isometric drawings or analogue models. While the digital architectural scale model is still a new medium there is neither a consensus about its theoretical foundations nor much awareness of the outcome at present. The models presented here differ much more from one another than a first glimpse on the visual results may suggest. Every model has its own specific starting point as a project, its own medial conception and its own techniques to deal with issues of space, types, content and visuality. The controversy about what is 'permissible' in scientific digital modelling, emphasizes the need to set clear parameters and paradigms that determine a digital model. The seemingly incomparable variety of approaches to the use of digital models as a tool for research shows clearly that we are only starting out in this field. Furthermore, it is obvious that every digital reconstruction and its renderings have their own style. Therefore, not only the technical possibilities and restrictions distinguish digital models. It also becomes possible to understand the intellectual background and the idea of what exactly constitutes history subscribed to by the contractors involved. The images these models create and the knowledge they transmit are deeply rooted in long-term cultural debates. In the end, such visualization of a great variety of aspects may well be one of the main qualities provided by the medium. Obviously, the digital reconstruction is flexible enough to be adaptable to different purposes and approaches and is able to build up a rich model of the past. In this sense, even now virtual models present very interesting objects for future scholarly research.

Unfortunately, most current projects do not have an answer to the question of what to do with the enormous collections of data that are necessary for making the reconstructions.[11] Future projects must evaluate the scientific achievements gained even by the architectural investigation of well-known historical data. A crucial issue at stake regarding further scientific exploitation relates to how these collections of data might be used as a pool of knowledge for research on residences and how expensive digital models might be extended or changed later on. As a result, the imaginary worlds created and manipulated by the extensive use of digital reconstructions, computer networks, external knowledge bases and internet references as well as the development of interactive games and internet tools therefore need to be supported by scientific discourse. Museums and archives for these immaterial cultural goods are thus an essential requirement.

In conclusion it remains for us to point out that the international standards in building digital models of lost palaces are rising steadily. Most researchers in this field use virtual reconstructions to doublecheck their theses. Digital projects exist on most palaces of main national and international importance. The future will bring additional tools aimed at interactivity and data exchange. We are curious where this technology will take us. In any case to see so many models and to read about their building process seems very promising. Either way, the digital model building leads to a new debate about the virtuality of our perception of palaces and residences of medieval and pre-modern times and thereby about our way of reconstructing and understanding history. Moreover, there is the potential of helping us in sharing our imagination and knowledge. As long as it may be ensured that researchers and scholars gain access to collections of reconstructions to the data and to the underlying evidence virtual reconstructions via digital models may quickly become interactive pools of knowledge serving science and the media.

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The Beginnings of Digital Visualization of Historical Architecture in the Academic Field

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When did the history of digital visualization of historical architecture start? Is there a precise date of birth? And, most importantly, when did Academia, in particular the discipline of art history, start to explore this new technology? The development of the digital visualization of historical architecture will be outlined in the survey below. So far, very little has been published on this topic from the point of architectural and art history.[1] In addition, this kind of overview has often omitted the direct relationship between technological development and scientific use of digital 3D models of historical architecture. Usually, such analyses are made from an archaeological point of view, often for pre-historical or ancient cultures. Therefore, in this essay the technological foundations and most significant precursors for the formation of 3D models of historical architecture shall be examined in addition to introducing some important early projects from the perspective of the history of architecture. Finally, the relevance of the establishment of appropriate academic institutions and conferences for the establishment of digital architectural models for research will be demonstrated.

The Visualization of Historical Architecture – a Matter of Technology

Three-dimensional representation of architecture by way of models has long been a tradition in post-classical European art history for centuries, although the medieval situation is far from certain. It has, however, been possible to prove that reduced-size buildings made from bricks were already in use in Italy from the middle of the 14th century to plan building projects such as Florence Cathedral.[2] From the 16th century onwards, models of entire cities were created.[3] A model of the city of Florence, made from cork in 1529 but lost today, is considered one of the earliest examples.[4] It was probably commissioned by Pope Clement VII for the purpose of espionage: he wished to understand the city's fortifications, with the intention to re-establish Medici rule over his hometown.[5] Only very few city models from that time have been preserved, such as the unique series of wooden models of Bavarian cities created by Jakob Sandtner, a wood turner from Straubing, between 1568 and 1574.[6] They were displayed in the Münchner Kunstkammer of Albrecht V, where they were accessible only to a small, select audience.[7] To this day, tangible architectural models are created from a wide range of materials – for example wood, paper, metal or plastic – and for diverse purposes such as helping with the design process and in competitions, exhibitions and presentations with a focus on architecture.[8]

The digital representation of historical architecture in the field of science has a much shorter history. The development of digital architectural visualization through the use of Computer Aided (Architectural) Design, CA(A)D, is directly linked to technical developments of both hard- and software. Today CAD is a standard technique predominantly used by architects for designing building projects. Its roots go back to the 1960s when Ivan Edward Sutherland developed *SKETCHPAD* at the Massachusetts Institute of Technology (MIT) in Cambridge, MA, while working on his doctoral thesis published in 1963.[9] With the help of that programme two-dimensional objects could be displayed on a screen and altered with a keyboard and a 'light pen' using a so-called 'interactive graphics terminal'.[10] This innovative programme offered a possibility for humans and computers to interact on a graphic level for the first time.[11]

Since at first the available technology did not meet the requirements of architects, it was primarily used for mechanical engineering.[12] Even in the 1970s CAD was limited to depictions of two-dimensional spaces and perhaps comparable to some kind of electronic drawing board.[13] In addition, the technology was beyond the reach of smaller companies, who could ill afford to pay for maintenance and for CAD experts.[14] Nonetheless, as early as 1973 the archaeologist John D. Wilcock, apart from four possible main applications of computer technology in the discipline of archaeology, identified reconstructions of culturally important buildings and monuments as a vital means of generating knowledge.[15]

In the field of art history, Werner Müller may be regarded as a pioneer of computer aided visualization of historical architecture. Together with Klaus Hänisch he demonstrated the benefits of the use of computer programmes for investigating vaults in their 1976 article *Die Möglichkeit einer computergesteuerten isometrischen Darstellung von figurierten Gewölben der deutschen Spätgotik (The possibility of a computerized isometric representation of figured vaults from the German late Gothic period)*.[16] By entering the relevant data in a particular programme, complex vault constructions could be quickly calculated by the computer and then be printed by a mechanical plotter. It also became possible to create schematic underdrawings and orthogonal views as well as isometric representations, which might eventually convey a spatial impression. While such a process was most likely not yet technologically viable in the late 1970s, Müller paraphrased his vision for the future as such: 'A graphic screen as a significant aid will allow rotating the object depicted and combine several views of a vault simultaneously. We hope that we will be able to report on progress in a later work.'[17] His vision only became reality in the 1980s.

Between 1978 and 1980, the research project *Aspen Moviemap*[18] had come up at MIT and was then called the 'first known large-scale digital capture of a contemporary city'[19] by the archaeologist Bernard Frischer. It may be categorized as yet another innovation in the field of digital visualization of architecture, in particular since panorama photography rather than the CAD programme was used. Three MIT students, Peter Clay, Bob Mohl and Michael Naimark, worked on *Aspen Moviemap* within the framework of the *Architecture Machine Group*.[20] With the help of synchronized cameras set on a wheeled carriage the three students took photographs of every street of the city of Aspen, CO, at short intervals.[21] Post-editing made the transition between the single images as seamless as possible.[22] As a result, the so-called 'interactive movie map' allows the user to move virtually through a location, which is thoroughly documented photographically, on a screen and without being there in person.[23] Nonetheless, the audience may still gain a visual and spatial impression of the city, while deciding for themselves in which direction they would like to move next (fig. 1).[24]

Fig. 1 The *Aspen Moviemap* experienced in the 'Media Room' at the Architecture Machine Group, MIT, ca 1980. The 'traveller', seated in an instrumented armchair, controls speed and direction of travel. Touch screens displaying map and aerial views allow access to additional multimedia material.

This was a technological innovation in the late 1970s, since video editing had rarely ever been done on computers by that time while analogue video footage, up to a maximum duration of 30 minutes, could be saved on 'optical videodiscs'.[25] Over the following years, several more moviemaps were created, some of which were accessible to the public in the form of museum installations.[26] These moviemaps of existing places may well be considered as the ancestors of the more recent Google Street View.

Digital Visualization of Historical Architecture in Academic Research

The enhancement of CAD technology in the 1980s first allowed for the three-dimensional virtual construction of architecture on the computer.[27] In 1984 Jim Clark, a former professor at MIT, developed an innovative procedure for the representation of 3D objects at his company *SGI* (Silicon Graphics Inc.), which he had founded in the early 1980s.

> 'Clark was initially focused on developing a powerful semiconductor chip (called the Geometry Engine) that would allow small computers to produce sophisticated three-dimensional graphics. The idea was revolutionary because before this, graphics simulations were often (if not only) done on large mainframe computers.'[28]

This groundbreaking development helped *SGI* to become the market leader in the early 1990s.[29]

In archaeology, the 1980s became a turning point. In his survey of the development of 'computer modelling' in archaeology Bernhard Frischer noted that the first contribution on the subject of 3D technology was made at the conference *Computer Applications in Archaeology* (CAA) held in 1985.[30]

Possibly the first digital 3D model of historical architecture based on archaeological data was created in the UK between 1984 and 1986.[31] Hosted at the IBM UK Scientific Centre the project focused on the building history of the Old Minster in Winchester, Hampshire, an Anglo-Saxon church from the early Middle Ages replaced by the present Winchester Cathedral in the 11th century (fig. 2).[32]

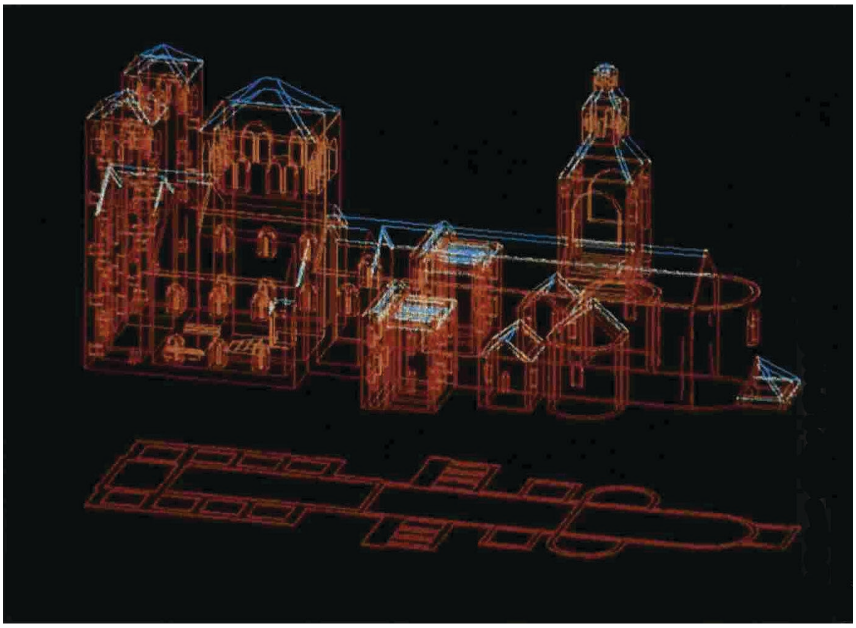

Fig. 2 Wireframe model of Old Minster created at the IBM UK Scientific Centre, Winchester, in 1984-1986.

The computer reconstruction could be viewed in the form of a two-minute video at the exhibition *Archaeology in Britain: New views of the past* at the British Museum in London from July 1986 to February 1987.[33] The video comprised a pre-set route through the 3D model and displayed both interior and exterior views of the Old Minster (fig. 3).[34]

Fig. 3 General view of the Old Minster reconstruction created at the IBM UK Scientific Centre in 1984-1986.

Other versions of the reconstruction were created for television broadcasts in the UK and depicted almost 400 years of building history of this church, from its supposed beginnings in AD 648 to its appearance in ca 1000.[35] The digital implementation was created with the help of the software *Winchester Solid Modeller* (WINSOM), which was on this occasion used for the first time in the field of archaeology.[36] Drawings and reconstructions created by the archaeologist Birthe Kjølbye-Biddle served as the basis for the digital modelling.[37] Those were yet again based on the archaeological excavations she had conducted in the 1960s and which had brought to light the partially surviving foundations of the old church.[38] Although the building had just been expanded in the 10th century, it was demolished in the year 1093.[39] Therefore, the computer reconstruction was used to visualize the lost medieval building for the first time since its destruction and to make its appearance digitally accessible to the public.[40] As a result, the digital model was not only exhibited in a museum, but also presented to a wider audience in several programmes on British television.[41]

Only a few years later the first 3D model of an archaeological medieval monument was presented at the *CAA* in 1989.[42] It was a computerized analysis of the no longer existing early medieval castle of Mathrafal in Wales, UK.[43] This project had started four years earlier and was supported by the IBM UK Scientific Centre as well as by several cultural institutions such as the Royal Archaeological Institute.[44] The goal was to research the site and its function, using new computer technologies.[45] The insights gained in this way were used to develop a strategy for the least invasive excavation possible.[46] Several different types of image and graphic editing software used at the IBM UK Scientific Centre in Winchester allowed for the processing of large amounts of data gathered in previous topographical and geophysical examinations and subsequently to turn the topographical data into a 'computer-generated three-dimensional wire-frame surface, or digital terrain model'.[47] Light and shade were added, relative to a hypothetical source of light.[48] The resulting analysis of the 3D model allowed the identification of terrain anomalies such as original locations of walls and buildings.[49] With the help of the programme *Winchester Solid Modeller* (WINSOM) these interpretations could then be visualized together with the newly collected data in a so-called 'reconstruction model' (fig. 4).[50]

Fig. 4 Solid terrain model with reconstruction of motte-and-bailey, Mathrafal in Wales, UK, generated in the late 1980s.

The archaeologist Paul Reilly points out the importance of this approach for archaeological research:

> 'In combining the interpretation with the measured data, it is very easy to see how the two categories of information relate to one another. At the same time attention is redirected to unexplained features or anomalies which are left exposed.'[51]

The use of these new computer technologies allowed, before even starting a new excavation, for the collection of new information about the historic site of Mathrafal that would have remained undiscovered otherwise.[52]

One of the first digital 3D models that visualized a complete city is that of Glasgow, Scotland.[53] In the 1980s students from the Department of Architecture and Building Science of the University of Strathclyde, UK, compiled a digital interactive 3D model of the city of Glasgow with CAD.[54] It was based on a digitized city map, measurements of the height of individual buildings as well as on aerial photographs. The data collected were finally laid over a three-dimensional terrain model of the city, which permitted real time 'fly throughs'. This was a technique also used for the visualization of other cities at the time.[55] Nonetheless, this project was only made publicly available in 1999, when the World Wide Web had taken hold and when it became possible to download parts of this online visualization and explore it virtually (fig. 5).[56]

Fig. 5 Left: typical interactive frame from *VRGlasgow*, here showing George Square in the city centre with the City Chambers (town hall) at the far end; right: multi-user interface to *VRGlasgow.*

The three-dimensional reconstruction and simulation of Cluny III from the year 1989 is one of the earliest projects to enter uncharted territories in the field of the reconstruction of individual buildings.[57] Directed by the architect Manfred Koob and his company *asb baudat* in Bensheim, Germany, this project marks an important step forward in the digital visualization of architecture: using CAD software, an architecturally complex building, of which only sparse remains were left, was digitally reconstructed for the first time (figs. 6a, b and c). There had never been a project of such scope before. 7337 individual components were constructed and merged into 320 assembly groups, which combined certain elements of the building. These reconstructions were then combined into bodies in a solid model and furnished with surface textures. In the beginning of October 1989 the project was completed after a construction phase lasting several weeks: as a result a four minute film with a simulated tracking was shot in and around the virtual Cluny, consisting of 6000 individual images.

The biggest church built in the Middle Ages, Cluny III in Burgundy (started in 1088) had been demolished after the French Revolution and was used as a stone quarry.[58] Until 1989, apart from a few remains of the building, the surviving information in the form of historical prints, paintings, plans, texts and a wooden model displayed in the Cluny museum were all that could be accessed.[59] The film, realized in 1989, formed part of the documentary *Auf den Spuren der Salier, Nomaden auf dem Kaiserthron (Following the Footsteps of the Salians, Nomads on the Imperial Throne)* of the Südwestfunk channel from Baden-Baden.[60] This TV programme had been produced in the context of the exhibition *Die Salier und ihr Reich (The Salian Dynasty and their Empire)* held in Speyer in 1992.[61] Therefore, the 3D reconstruction offered a detailed visual approach to a complex building no longer in existence.

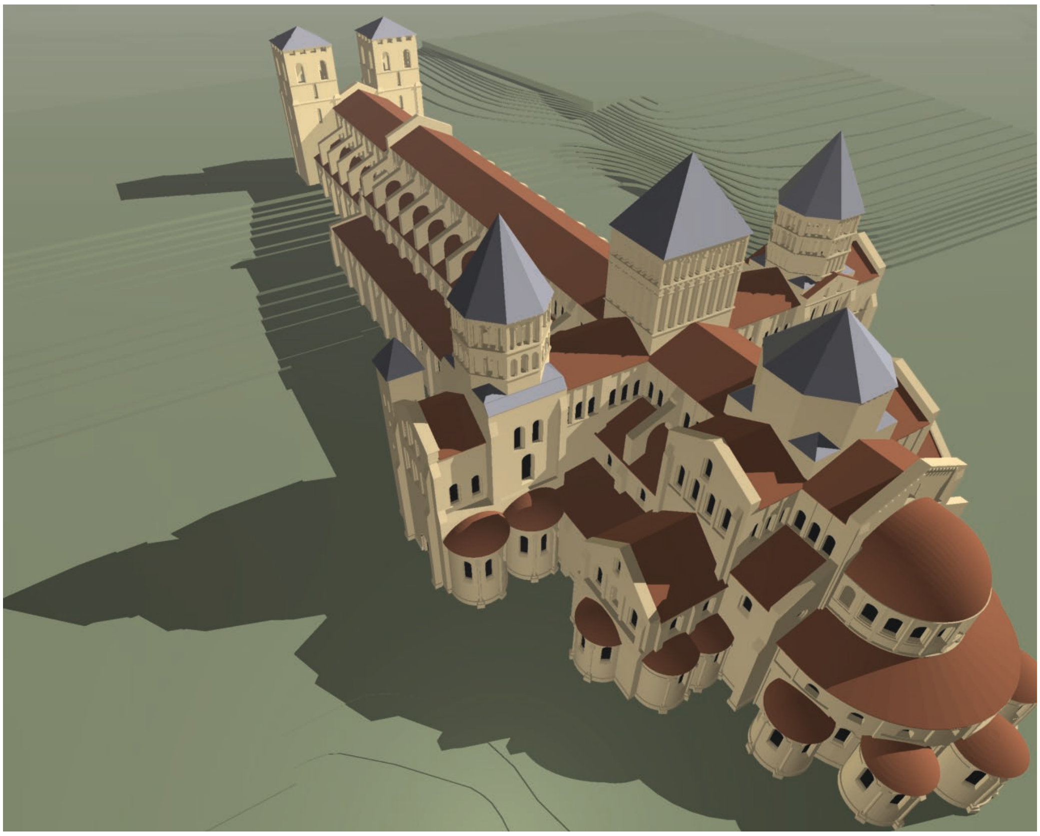

Fig. 6a 7337 individual components were merged into 320 assembly groups, which make up the complete structure of Cluny (digital reconstruction of Cluny III in 1989).

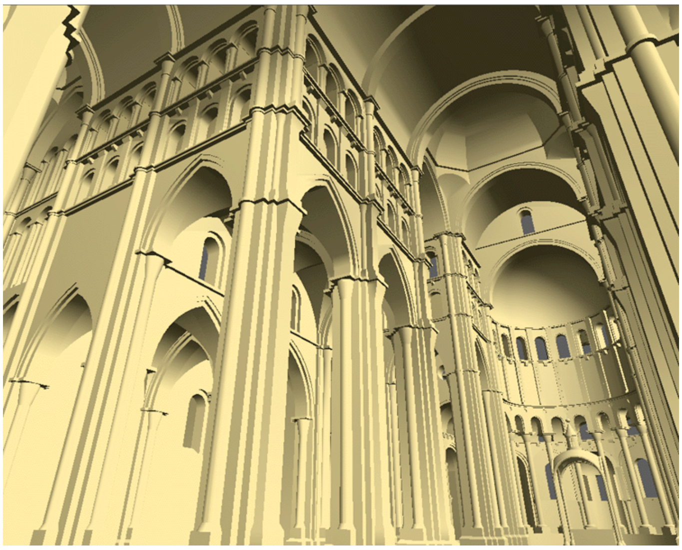

Fig. 6b View of the interior of the digitally reconstructed church Cluny III (1989).

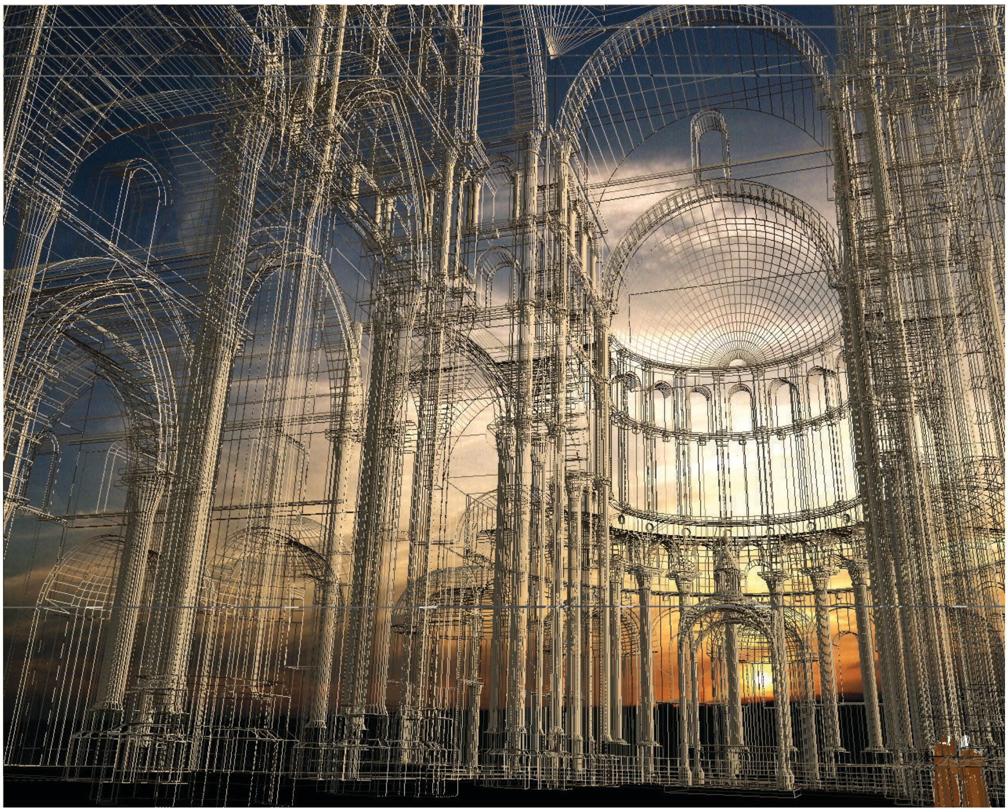

Fig. 6c Wireframe model of the digitally reconstructed church Cluny III (1989).

As these examples illustrate, the application of computer programmes such as CAD to issues concerning the history of architecture became crucial in the 1980s. In his dissertation *Computer-Assisted Architectural-Historical Research,*[62] published in 1991, Ronald Stenvert identified three concrete areas of application of CAD in this field:

> 'Firstly, that of architects restoring existing buildings who use CAD in the designing and drawing process. Secondly, there are the first tentative attempts of architectural historians in this field, and thirdly the more fundamental but also, to say the least, rather abstract attempts of architects teaching at institutes of technology.'[63]

Here, it becomes clear that architectural historians dealt with CAD in an academic context even before 1991. It seems to have been the case only for a small amount of projects. This was caused by the fact that CAD was used at first almost exclusively to design new architecture, for technically it was nearly impossible at this time to analyze digitized drawings of existing buildings with CAD programmes.[64] Art historians, for example, simply lacked the knowledge necessary to develop their own software that met their standards. Unlike architects, art historians were not interested in designing new buildings but in researching previously-existing buildings at the computer.

At that point in the history of architecture, computers opened up another new field of research with the possibility to create floor plans systematically and according to a specified set of rules. In the 1980s, Richard Freedman and George Hersey developed a computer programme, which made it possible to construct the ground plans of hypothetical villas by the architect Andrea Palladio (1508-1580).[65] Palladio's villas were based on ground plans constructed in accordance with precise rules regarding symmetry and proportion. Freedman and Hersey were able to deduce the fundamental rules from plans in the second book of his work *Quattro libri dell'architettura.*[66] Thomas Seebohm, professor of architecture at the University of Waterloo, Canada, developed their research in the 1990s and expanded it by creating digital 3D models based on computer-constructed plans (fig. 7).[67]

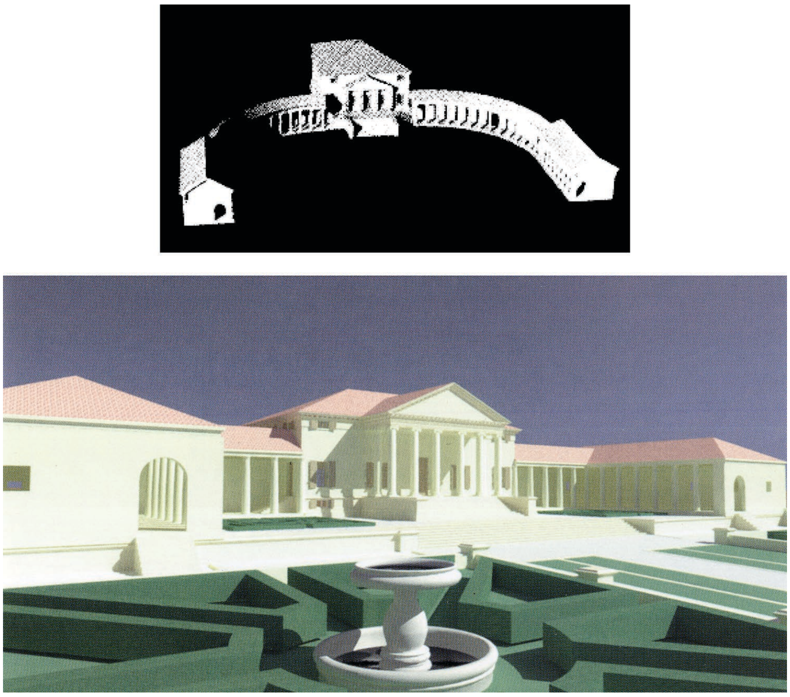

Fig. 7 Computer reconstructions of possible Palladian villas by Thomas Seebohm: above, model of the Casa di Villa and its barchessa, first scheme (1991); below, a different version of a Palladian villa with its geometrically laid-out garden (early 1990s).

In addition, he did not solely examine the central structures of the villas by Palladio, but also included the lateral wings and the renaissance gardens pertaining to the buildings in his investigations.[68] On the basis of this study, published in 1991, further design rules employed by Palladio could be uncovered by means of creating 3D models.[69] An on-going comparison of computer generated plans of Palladio's designs and of his completed villas proved to be very helpful for getting better insights in his *modus operandi*. Therefore, the goal of Seebohm's study – i.e. to offer a suitable methodology for the critical analysis of architecture – was met.

As far as digital reconstruction is concerned, the early academic work of architectural historians seems to have focused predominantly on urban structures.[70] Two-dimensional cadastral maps were enriched with historical information early on by means of the digital tool of Geographical Information Systems (GIS): for example, a *Historical Urbanistic Information System* was developed for the Dutch city of Maastricht in the early 1990s.[71]

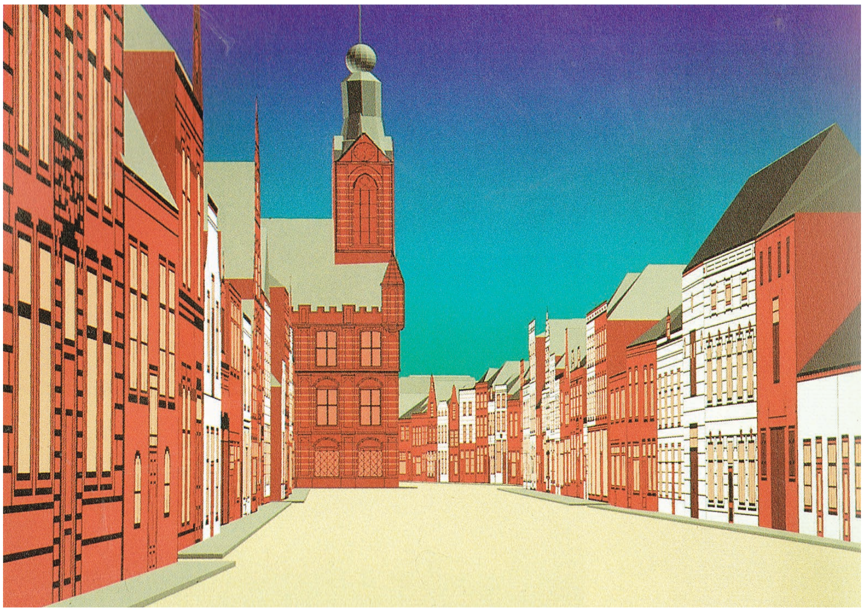

Fig. 8 Patricia Alkhoven's computer reconstruction (1993) of the city of Heusden, showing a view of the main street and Town Hall in 1943.

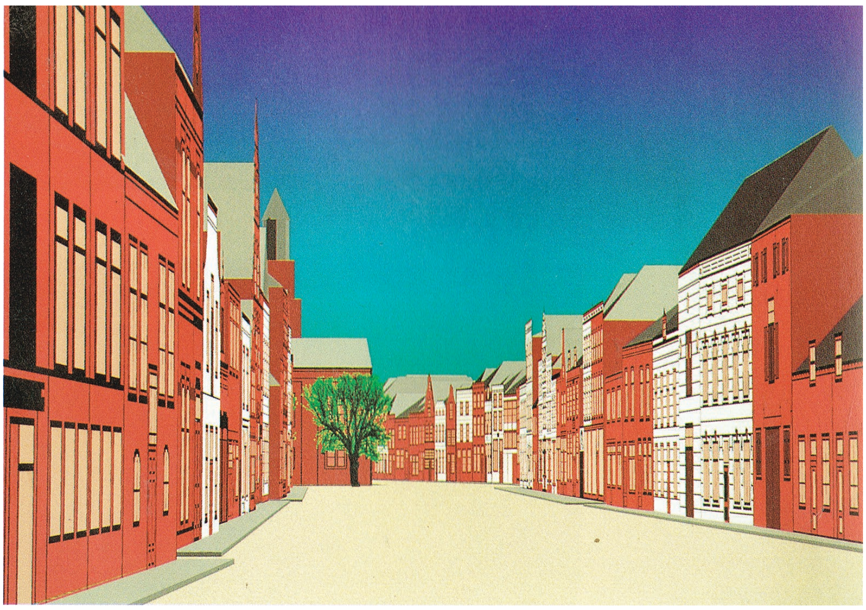

Fig. 9 Patricia Alkhoven's computer reconstruction (1993) of the city of Heusden, showing a view of the main street and Town Hall in 1990.

In her thesis published in 1993, the architectural historian Patricia Alkhoven compared historical maps of the city of Heusden in the Netherlands with contemporary cadastral maps with the help of the computer.[72] She digitally layered the plans and maps to allow her to make much more precise statements about the reliability of the historical sources than had been possible by manually placing two printed maps side by side. From 1989 onwards, Alkhoven examined at the University of Utrecht how new technologies could advance research on the history of architecture and created a three-dimensional CAD model of the city of Heusden on the grounds of historical and current maps. Her objective was to visualize digitally the evolution of the townscape as well as to investigate the use of this technology in relation to its contribution to the gaining of knowledge. The subject of the digital visualization of the city of Heusden is the well-documented urban development in the 20th century when the city was undergoing extensive remodelling of the historical structures in two phases of restoration. Between 1965 and 1978, selected buildings within the city and in particular near the harbour were restored to their historical appearance. Subsequently, from 1978 until 1990, fake historical buildings were erected, city gates reconstructed and single town houses brought back to former splendour. With the help of a so-called micro computer,[73] Alkhoven created 3D models of the city that illustrate key moments of its history (figs. 8 and 9). Thereby users gained the possibility to pick any given point in any view and to compare the changes in the layout of the city between the individual 3D models.[74] In that way, dynamic processes of transformation in the evolution of the city could be visualized and analyzed by a contrasting juxtaposition. Her work revealed that the use of computer programmes supported research in manifold ways, since they were faster and more precise than conventional methods of creating drawings or tangible models.

The abovementioned pioneer of art historical research in computer-based reconstructions of historical architecture, Werner Müller, composed computer graphics that visualized the design process for late Gothic decorative vaults together with the mathematician Norbert Quien, in the early 1990s.[75] Between 1989 and 1993, this undertaking was supported by the DFG (Deutsche Forschungsgemeinschaft – German Research Foundation) within its project *CAD of Late Gothic Vaults* under the direction of Prof. Dr. Willi Jäger, then in charge of the Interdisciplinary Center for Scientific Computing (IWR) in Heidelberg.[76]

Due to the strict set of rules for designing the rib system, Müller and Quien were able to reconstruct vaults that no longer existed by using algorithms and traditional plans.[77] Therefore, they created computer graphics, for example of a late Gothic church choir based on a plan from the so-called 'Stromersches Baumeisterbuch' from the end of the 16th century (figs. 10 and 11).[78]

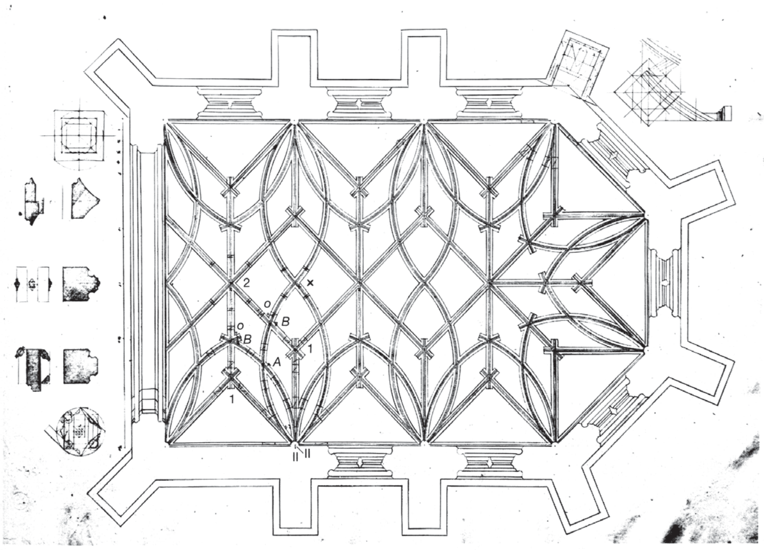

Fig. 10 Floor plan for a late Gothic church choir in the 'Stromersches Baumeisterbuch' I, end of the 16th century.

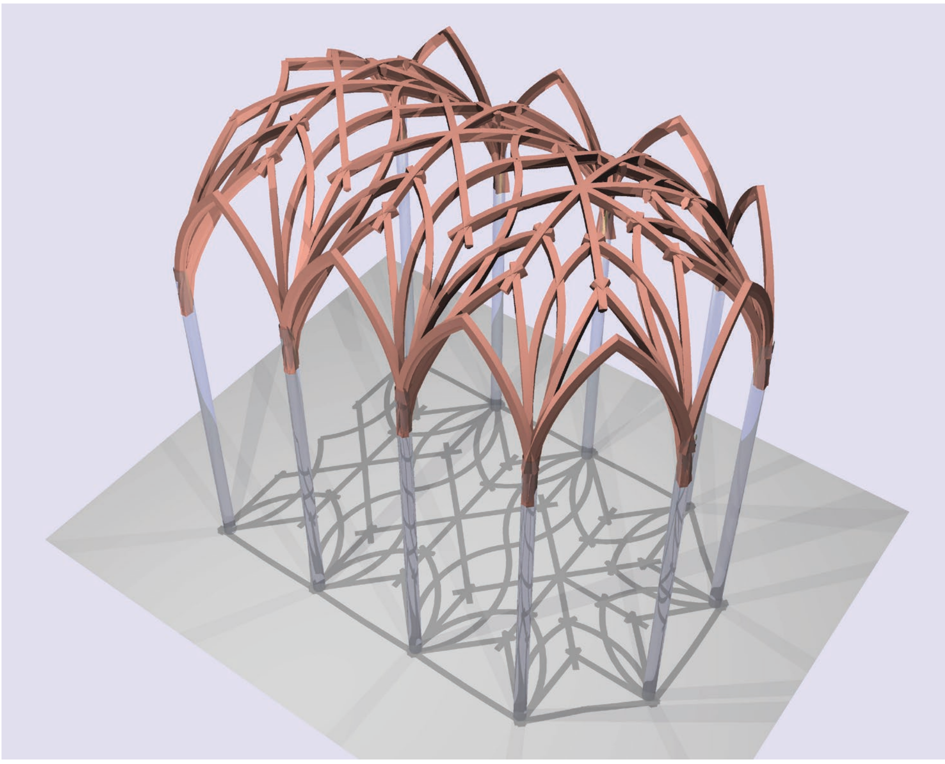

Fig. 11 Digitally reconstructed structure of a vault by Werner Müller and Norbert Quien, lit from above with parallel light. The shadow, a projection of the three-dimensional shape into the horizontal plane, is identical to the original plan (compare fig. 10), state 1991.

Now it became possible what Müller had envisaged in 1976: several views of the reconstructed building might be visualized at the computer screen (fig. 12).[79]

Fig. 12 Digital display of a church choir by Werner Müller and Norbert Quien (1991). The shape of the vault and the window profiles are derived from designs in the 'Stromersches Baumeisterbuch' (Nuremberg, ca 1590), which were test pieces for an examination for the master craftsmen's certificate and were not intended for actual building (compare fig. 10). The floor is modelled on a medieval example.

In September 1999, the exhibition *Hammer, Meißel und Computer. Spätgotik im rechten Maß,* which presented the results of years of work on the reconstruction of late Gothic vaults by Müller and Quien, started at the *Landesmuseum für Technik und Arbeit* (LTA – State Museum of Technology and Labour, now being called *Technoseum*) in Mannheim.[80] It featured printouts of the CAD models, whose background and development were explained in the accompanying publication of the LTA.[81] Müller and Quien continued their intensive engagement with this project for years and wrote publications on the subject until Werner Müller's death in 2005.[82]

One of the first digital reconstructions of a palace was developed in the early 1990s in the UK: A computer model was made for the visitor centre of Dudley Castle in the West Midlands to be used in an interactive installation, inaugurated by Queen Elizabeth II in 1995.[83] The archaeologist Peter Boland and Colin Johnson, then a freelance computer artist, reconstructed in a computer model Dudley Castle, the Renaissance castle of the influential Sir John Dudley, Duke of Northumberland, as it would have looked in the 1540s (figs. 13 and 14).

Fig. 13 Dudley Castle, the Sharrington Range built by Sir William Sharrington for John Dudley, Duke of Northumberland, in its present-day state.

Fig. 14 Computer visualization of the state of Dudley Castle ca 1550 by Peter Boland and Colin Johnson (1994).

The site is also known as Sharrington Range, named after the architect Sir William Sharrington, who erected several buildings for the duke at that time. These buildings are the focus of the 3D model, which visualizes both interior and exterior views (figs. 15 and 16).

Fig. 15 The ruined chapel of Dudley Castle in its present-day state.

Fig. 16 Computer visualization of the chapel, a private place of prayer next door to his lordship's chamber by Peter Boland and Colin Johnson (1994).

The interactive viewing station in the exhibition at Dudley Castle was designed as a 'virtual tour'. The visitor may follow a pre-set route through the castle, but also has the option to move around the computer model at will by using three buttons (left, right, forward). A commentary, allegedly by Lord Dudley's steward, enhances the virtual visit. The reconstruction of the castle was based on the existing ruins, the results of the archaeological excavations conducted in the 1980s as well as on records, consisting of historical views and written documents. A historian advised on the virtual interior design with period furniture. Nonetheless, Boland and Johnson emphasized that their computer reconstruction visualized interpretations and assumptions regarding the historical look of the castle and did not represent actual facts. This interactive application, designed for an exhibition, was one of the first in the field of Virtual Reality[84] and remained in use in the exhibition area of the castle until 2005.[85] Therefore, the computer reconstruction was an early example of the collaboration between scholarship and technology with the aim of explaining historical circumstances in an interactive presentation for museum visitors.

Another digital reconstruction intended for the public was that of the Dresden Frauenkirche (Church of Our Lady) in the early 1990s. At the time only few remains of the church, almost completely destroyed during World War II, were left in the centre of Dresden. Only after The Fall of the Berlin Wall the plan to rebuild the church became feasible when the *Gesellschaft zur Förderung des Wiederaufbaus der Frauenkirche Dresden e.V. (Society for the promotion of the reconstruction of the Dresden Frauenkirche)* was founded with the goal of collecting donations.[86] At the start of this project, which would last for more than ten years, an extensive digital model of the Frauenkirche was created in only twelve weeks using the CAD software CATIA (Computer Aided Three-dimensional Interactive Application). The interior and exterior views were visualized both in their ruined state as well as in the way they would look after the completion of the re-building. The animation of the finished 3D model served as an advertisement for the fund raiser.[87] A team, consisting of technicians, curators and archaeologists, researched the sources and was also responsible for the technical implementation of the information in a digital model.[88] Historical photographs as well as architectural drawings, which had been created during a previous restoration campaign in the years between 1938 and 1943, served as the basis for the visualization project. Architectural details were only depicted if there was evidence for them in the source materials, since the project was supposed to meet the standards of being both historically correct and of achieving the authentic effect and atmosphere of the digital Frauenkirche. To do so, historical photographs were used as textures on the geometrical model. Thereby, the decorations inside the dome were also visible in the 3D model. Music was added to the completed animation of the computer reconstruction, which lasted three minutes and 35 seconds in total.

One of the biggest long term virtual reconstructions to be made in the context of academic research in the 1990s was *Rome Reborn.*[89] It is a very detailed, comprehensive digital 3D model of the city of Rome, which is still work in progress to this day.[90] It visualizes the development of the city of Rome between 1000 BC and 550 AD.[91] The project was started in 1995 at the University of California, Los Angeles (UCLA) in the form of an international collaboration of several disciplines such as architecture, classics and information science in the USA, in the UK and in Italy.[92] The objective of this project is to visualize the topography and the evolution of the city of Rome over a long period of urban development.[93] The first 3D model created under the auspices of this project dates from the year 1996 and shows the temple of Antonius and Faustina (fig. 17).[94]

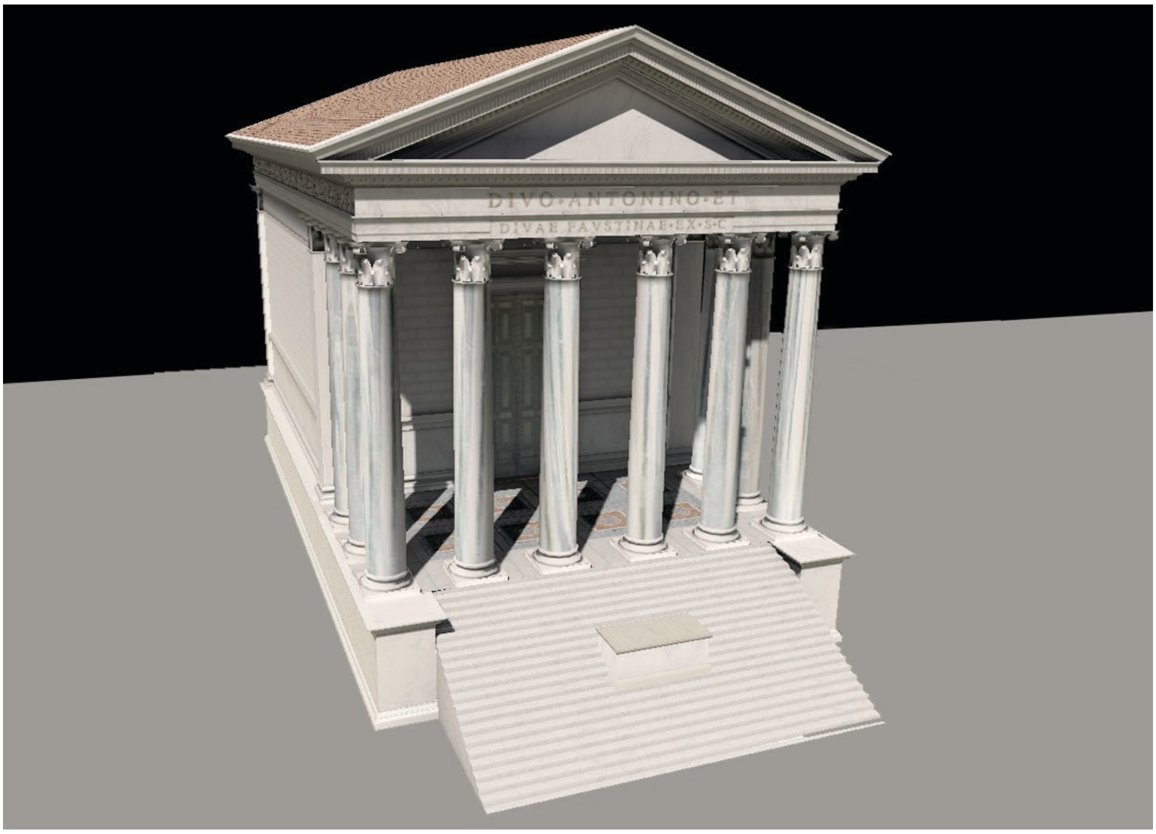

Fig. 17 Antoninus et Faustina, templum. Imperial cult temple commemorating the Emperor Antoninus Pius and his wife, Faustina. Reconstructed state: Building as first dedicated. Here: Reconstruction view. First 3D model of the *Rome Reborn* project (1996).

Since people have been working on the project *Rome Reborn* continuously for decades, several versions have arisen, each of which represent a different state of knowledge and current research on ancient Rome.[95] As there are only very few sources for some of the buildings, different hypotheses may be tried out and checked in the digital 3D model, in order to discuss them afterwards in a team of experts.[96] One example for this procedure is the digital reconstruction of the church of Santa Maria Maggiore, completed in 1999, as part of *Rome Reborn.* A scientific committee of researchers from different disciplines was responsible for this part of the project, under the direction of Diane Favro of the UCLA Department of Architecture and Urban Design. As a project leader, the archaeologist Bernard Frischer of the Department of Classics at the UCLA regularly checked the work on the model concerning its historical correctness and the data used for the reconstruction. The researchers involved in this reconstruction entertained two different hypotheses regarding the design of the entrance to the nave (fig. 18).

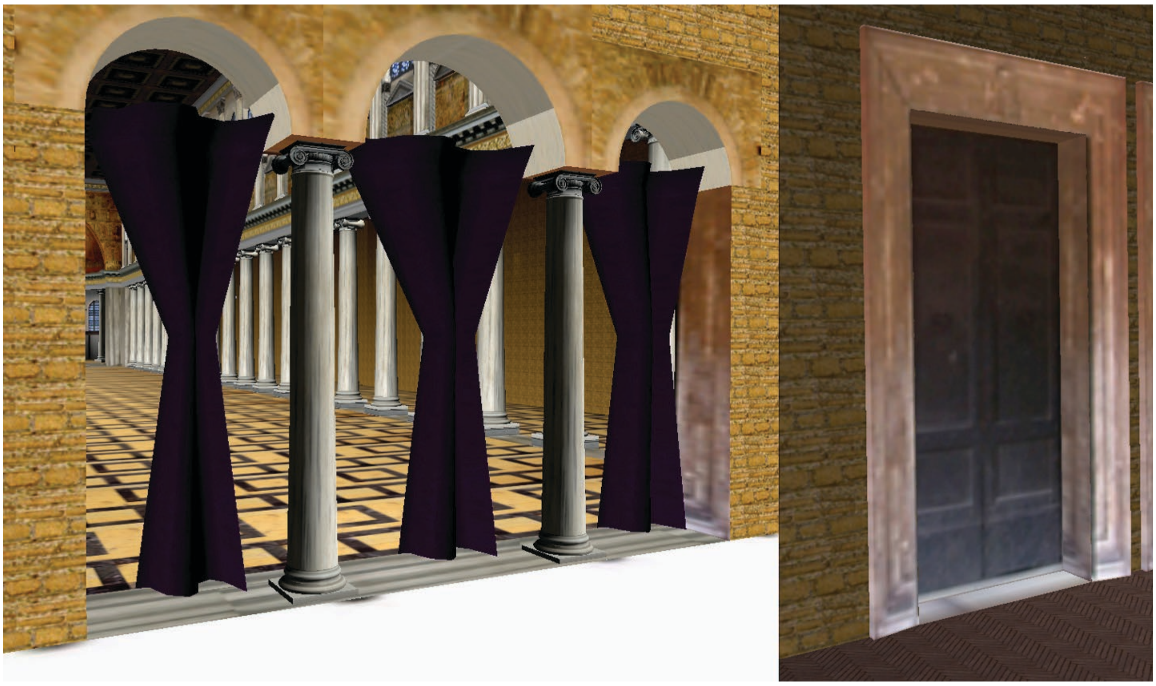

Fig. 18 Alternative reconstructions of the front entrance of the Basilica of Santa Maria Maggiore (left: curtained openings of the final version; right: doors in an earlier version), part of the *Rome Reborn* project (1996).

At first, both versions were visualized in the model until the final decision for one or the other was reached. This procedure illustrates that a 3D model is not a static object but can be updated regularly, depending on the current state of research concerning the object under debate. In *Rome Reborn* the scientific committee was able to class one particular condition of the model as 'certified' and thus to allow future changes only with the agreement of the committee.

These examples make clear that, starting in the 1980s and even more so in the 1990s, several digital 3D models of historical architecture were realized, based on scientific examinations, in innovative projects. The most recent technologies like CA(A)D and 3D graphical systems were used in a vast range of contexts within the cultural sciences. All those projects, usually depending on the cooperation of different disciplines, brought innovations into the research on architectural history with the help of computers and conveyed information about the digitally reconstructed buildings to a wider audience with the use of new technological possibilities.

Institutionalization – Framework and Fertile Ground

In the 1990s, the field of creating digital 3D models of historical architecture was growing fast, as the rising number of projects presented at conferences demonstrates. This development may certainly not solely be explained with computer technology becoming more widespread and affordable,[97] but also with the institutionalization of research on digital depictions of architecture. It is worthwhile to look briefly at this historical development: CAD was introduced as a tool to students of architecture in different universities in the USA and Europe in the 1970s[98] and 1980s.[99]

One of the first conferences on the use of computers in archaeology was organized by the already mentioned international Organisation *CAA* (Computer Applications & Quantitative Methods in Archaeology) and had been held in Birmingham, UK, in 1973.[100] The *CAA*, founded by archaeologists and mathematicians, permitted scientists to present their research by using different computer technologies in annual international conferences.[101] One important subject was the digital reconstruction of three-dimensional objects and architecture. Even today, the annual conferences of the *CAA* are highly respected, in particular in the field of virtual archaeology, as becomes evident by the growing internationalization of the conferences, since 2006 also held in non-European countries.

Already in the early 1980s individual institutions arose, which dealt with the academic usage of CAD. As an early example may serve the non-profit organization *ACADIA* (Association for Computer Aided Design in Architecture), which was founded in the USA in 1981 and advanced the cultivation of networks between scientists in the field of digital design.[102] Every year they organize conferences at alternating North American universities as a forum for the architectural computing community in which to present innovative technologies and applications.[103] *ACADIA* is closely connected to four other international sister organizations dedicated to the scientific exchange in the field of CAAD.[104] They were founded in the 1990s and in the 2000s respectively, with the exception of the non-profit organization *eCAADe* (Education and Research in Computer Aided Architectural Design in Europe), founded back in the 1980s.[105] Since 1983, *eCAADe* has been connecting institutions working in research and education in the field of CAAD and organizes annual conferences and workshops in cooperation with different universities all over the world.[106] Apart from actively promoting young academics by way of travel grants and special workshops for postgraduates, *eCAADe* also supports the exchange between more experienced scholars, for example by initiating the web-based publication platform *CumInCAD* for scientific publications on the subject of CAD.[107] This particular online database puts *eCAADe* in an extraordinary position, since it connects all sister organizations and reaches out to a broad international audience.

The trend towards the development of expert centres intensified in the 1990s. These days, a great number of academic institutes and scientific institutions are being founded and explicitly dedicated to the research on virtual reality[108] and CA(A)D, forming interdisciplinary networks and promoting young academics. Distinct spaces are being set up, as well as innovative fields of activity and areas of responsibility, which further the establishment of science and research on CAD.

One of these early institutions is the *Environmental Simulation Center* (ESC), founded in 1991 at the New School for Social Research, New York City, which is still active today.[109] ESC consider themselves as a research institution working for architects and city planners. Their projects include 3D models of urban spaces used for the analysis of city planning projects and their effects on the environment and urban development. An early project of the ESC is a computer generated model of Manhattan, which was used by the New York City planning office in 1993 to examine the building development guidelines for a particular residential area in Manhattan.

The two professors Bernhard Frischer and Diane Favro also followed an innovative approach when they set up a *Cultural Virtual Reality Laboratory* (CVRLab) at UCLA in 1997.[110] They intended to apply and research new digital technologies in the field of cultural heritage.[111] Their objective was to create digital architectural models in a scientifically correct way.[112] This could be ensured by 3D models being created by architects who were also trained historians and by an international team of scientists appraising the projects.[113] The initiative originated from a project on the reconstruction of Trajan's Forum (fig. 19).[114]

Fig. 19 Still from the real time simulation model of Trajan's Forum, created between 1996 and 1997.

For the exhibition *Beyond Beauty: Antiquities as Evidence* at the Getty Center in Los Angeles, Trajan's Forum was realized as a real time simulation model between 1996 and 1997.[115] With the help of the model, it was possible to present works of art in their spatial context to the audience. An online tour through Trajan's Forum was offered in addition to the exhibition.

Regular conferences contributed substantially to the institutionalization of research in the field of CA(A)D. In the 1990s, many international events related to this subject matter were established, most of which considered as important innovators in their respective areas.

The first conference of the international group *EVA* (Electronic Visualisation and the Arts) was held in London in 1990.[116] The subjects range from the application of new technologies in the area of visualization to education in the cultural sector.[117] Over the years, additional conference locations, for example Berlin, Moscow and Jerusalem were added, where to date conferences with a specific focus aimed at academic as well as economic audiences are held annually.[118] In 1996, the interdisciplinary conference *EVA Berlin* (Elektronische Medien & Kunst, Kultur, Historie) took place for the first time.[119] The majority of contributions dealt with 3D models of architecture and other objects as well as with current technologies in the area of 3D.[120] To this day, *EVA Berlin* is an annual forum for both scholars of the humanities and media and information scientists as well as for cultural institutions and related businesses.[121] There are contributions on the subject of 3D visualization and its application held every year.[122]

The International Conference on Virtual Systems and Multimedia (VSMM), which was established in 1995, is also held in changing locations all over the world.[123] Its focal point is on research related to 3D technology and multimedia visualization in the interdisciplinary field of history, art, technology and engineering.

Final Thoughts – About the Reception of Digital Visualization of Historical Architecture

When looking for the origins of digital visualization of historical architecture, a look at the second half of the 20th century shows that the starting point of the creation of 3D models of historical architecture may be found in the 1980s. Nonetheless, the development of CA(A)D technology and the ideas underpinning it actually stem from the early 1960s. The project SKETCHPAD revolutionized the work with computers in 1963, since it allowed for an interaction between humans and machines at the computer screen for the first time. The first three-dimensional models of historical architecture could first be created in the 1980s with the help of specialized 3D graphic systems. Scholarly projects from that early phase were almost exclusively attached to and conducted at universities. They became the breeding grounds for the interest in the source-based and scientifically correct visualization of historical architecture.

The projects from the 1980s and 1990s presented here, built upon the latest technological possibilities available at the time. All of them provided knowledge on historical context and even partially illustrated developments and progress of urban structures. They were rooted in issues related to the delivery of additional benefits to the research undertaken. The completed projects could be found in rather diverse contexts, independently from whether they were used in museum exhibitions, as an addition to documentaries, as a source of information and a simulation model in city administrations or even as online applications. They were mostly aimed at the laity, who thus received information in an innovative way by new technologies. It is worth noting that many of the digital reconstructions from the 1980s were also shown on TV, either as an addition to museum exhibitions or even as animations specifically made for the programme. Before the age of generally accessible internet and the invention of the World Wide Web in ca 1993, television held a highly important role: it shared new scientific discoveries with a wider audience by means of new computer technologies.

The quick advancement and establishment of CAD applications in the research on architectural history is mostly due to technological innovations. Nonetheless, the great influence of especially established non-academic institutes in the field of digital visualization of historical architecture, as well as conferences specifically targeted at it, ought not to be overlooked, since they made an institutionalization of the subject possible in the first place. Only then, a widespread public perception of the importance of the subject could be effected, as well as the scholarly recognition by the international research community. The area of digital visualization of historical architecture also experienced these processes, as shown earlier.

Nevertheless, the presentation of this development in a historical overview poses one difficulty not to be underestimated. As we know today, digital long-term preservation is a very important aspect that received little attention in the 1980s and 1990s. Occasionally images, in a few instances even videos, may be found on the internet, but certainly not from every 3D project ever undertaken. In addition, most of these works are hardly documented in publications at all. It is completely unclear to what extent the original data and the corresponding soft- and hardware are still preserved and accessible today. It would be desirable that the digital preservation should be included in the planning of the project from the outset and technologically implemented. Otherwise, the many innovative and work-intensive 3D models of historical architecture will be forever lost to research, similar to some of the demolished buildings that they digitally reconstructed.

Another, equally important step to prevent oblivion are the catalysts of research: International conferences on the subject, such as the *EVA, CAA* or *The International Conference on Virtual Systems and Multimedia*. Annually held conferences are also organized by institutions that are specialized in the scientific application of CAD, like *ACCADIA*, for example, or *eCAADe*. The current state of technological requirements and the questions regarding content, which are connected to the development of 3D architectural models, can be easily gathered from the contributions to the conferences. Universities and conferences, sharing a role as host institutions or as open forums, create the breeding ground for scientific projects on 3D models of historical architecture: they facilitate the development of technologies, the conception and implementation of projects, and promote the dissemination of knowledge and information, as well as international networking and exchange.

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Illustrations

Fig. 1 Photo: Bob Mohl, MIT 1980, in: Naimark 2006, fig. 1. Photo provided by Michael Naimark.

Fig. 2 Image provided by Paul Reilly. To be found in: Reilly 1992, Colour Figure 12.5.

Fig. 3 Images provided by Paul Reilly. To be found in: Reilly 1992, Colour Figure 12.3.

Fig. 4 Image provided by Paul Reilly. To be found in: Reilly 1992, Colour Figure 12.11.

Fig. 5 Image provided by Thomas Maver. To be found in: Maver 2002, p. 95, fig. 1.

Fig. 6a-c Images by Architectura Virtualis GmbH, cooperation partner of TU Darmstadt. Image provided by Egon Heller, Architectura Virtualis GmbH.

Fig. 7 Both images provided by Almuth and Margaret Seebohm. Image on the top to be found in: Seebohm 1991, p. 144, fig. 6. Image on the bottom to be found in: Novitski 1998, p. 81.

Fig. 8 Image provided by Patricia Alkhoven. To be found in: Alkhoven 1993, colourplate 17.

Fig. 9 Image provided by Patricia Alkhoven. To be found in: Alkhoven 1993, colourplate 18.

Fig. 10 Image provided by Norbert Quien. To be found in: Quien and Müller 1991, p. 125, fig. 4.

Fig. 11 Image provided by Norbert Quien. To be found in: Quien and Müller 1991, p. 127, fig. 6.

Fig. 12 Image provided by Norbert Quien. To be found in: Quien and Müller 1991, pp. 120-121, fig. 1.

Fig. 13 Image provided by Colin Johnson. To be found in: Website of 'exrenda', an online archive by Colin Johnson about 'Computer Visualisation of Dudley Castle c1550': http://www.exrenda.net/dudley/sharrington01.htm (last accessed on 02.02.2015).

Fig. 14 Image provided by Colin Johnson. To be found in: Website of 'exrenda', an online archive by Colin Johnson about 'Computer Visualisation of Dudley Castle c1550': http://www.exrenda.net/dudley/sharrington01.htm (last accessed on 02.02.2015).

Fig. 15 Image provided by Colin Johnson. To be found in: Website of 'exrenda', an online archive by Colin Johnson about 'Computer Visualisation of Dudley Castle c1550': http://www.exrenda.net/dudley/chapel.htm (last accessed on 02.02.2015).

Fig. 16 Image provided by Colin Johnson. To be found in: Website of 'exrenda', an online archive by Colin Johnson about 'Computer Visualisation of Dudley Castle c1550': http://www.exrenda.net/dudley/chapel.htm (last accessed on 02.02.2015).

Fig. 17 Image provided by Bernard Frischer. To be found in: Website of the project *Digital Roman Forum*, which was created by the CVRLab of the UCLA between 2002 and 2005: http://dlib.etc.ucla.edu/projects/Forum/reconstructions/AntoninusetFaustinaTemplum_1 (last accessed on 02.02.2015).

Fig. 18 Image provided by Bernard Frischer. To be found in: Frischer et al. 2000, para. 3, 'Identification of historical and archaeological research issues', fig. 4.

Fig. 19 Image provided by Lisa Snyder, *Urban Simulation Team*. See information about the reconstruction on the website of the *Urban Simulation Team:* http://www.ust.ucla.edu/ustweb/Projects/trajans_forum.htm (last accessed on 02.02.2015).

[1] The archaeologist Paul Reilly gives a relatively early outline of the usage of 3D models in archaeology in his 1992 essay, where he describes several projects from the 1980s to 1992 and the technology they used (Reilly 1992). Only a few years later the archaeologists Maurizio Forte and Alberto Siliotti summarize the contemporary situation in the area of digital cultural heritage in 1997 (Forte and Siliotti 1997). However, this overview almost exclusively refers to 3D models that have not been made by scientists but by private companies, as the archaeologist Bernard Frischer remarked in 2008 when he wrote his own historical outline, focusing on the usage of digital technologies in archaeological research (Frischer 2008). Only a year after the publication of Forte and Siliotti, B. J. Novitski edited a richly illustrated book about digital architectural models which were created mainly by scholars from different disciplines all over the world in the 1990s. The projects described dealt with reconstructed lost architecture, for example, or buildings designed by famous architects which were never actually built (Novitski 1998). In 2002, Frischer published a short summary of the technological developments and surrounding conditions in which digital 3D models were created with three other well-known experts of the field of 3D visualization (Frischer et al. 2002, pp. 7-18). A current outline is given by the architect Mieke Pfarr in her dissertation, published in 2010, where she focuses heavily on so-called digital reconstruction (Pfarr 2010, here: pp. 12-15). A very recent overview of digital reconstruction of historical architecture created by the company Architectura Virtualis in Darmstadt, Germany, over the last 25 years was published by the architects Marc Grellert and Mieke Pfarr-Harfst in 2014 (Grellert and Pfarr-Harfst 2014).

[2] Lepik 1995, p. 11.

[3] Reuther 1994, p. 11.

[4] Martin 1999, pp. 66-67.

[5] Ibid.

[6] One of the newest works on Jakob Sandtner is an essay by the art historian Heike Messemer referring to her yet unpublished master's thesis, which adds new findings about the creation of the city model of Straubing from 1568 (Messemer 2015 and Messemer 2011). The most comprehensive publication is from 1967, which deals with all five of Sandtner's models: Reitzenstein 1967. See Hoppe 2014, S. 266-267.

[7] Messemer 2011, p. 43.

[8] Oswald 2008.

[9] Sutherland 2003 (1963); and Mitchelll 1977, p. 14-15. William J. Mitchell is one of the first to deal extensively with CAAD and its functions and uses in his publication 'Computer-aided architectural design' from 1977 (see Stenvert 1991, p. 98).

[10] Mitchelll 1977, pp. 14-15.

[11] Rooney and Steadman 1987, p. 1-2, cited in: Stenvert 1991, p. 98.

[12] Stenvert 1991, p. 98.

[13] Choo 2004, p. 21.

[14] Steele 2001, p. 216.

[15] The four main uses according to him were: 'data banks and information retrieval; statistical analyses; recording of fieldwork; and the production of diagrams.' Cited in Frischer 2008, p. vi. and see Wilcock 1973, pp. 18-20. About the mention of computer reconstructions see Wilcock 1973, esp. p. 20 about the key word 'Miscellaneous Applications'.

[16] Müller and Hänisch 1976, pp. 339-341. About the information on vault reconstruction by Müller and Hänisch see ibid.

[17] Ibid. p. 341. (The original quotation in German: 'Eine wesentliche Hilfe wird dabei der graphische Bildschirm bieten, der es gestattet, durch Drehen des Objektes verschiedene Ansichten eines Gewölbes kontinuierlich ineinander überzuführen. Wir hoffen, darüber in einer späteren Arbeit berichten zu können.')

[18] A very elaborate documentation of 'ASPEN Movie Map' can be found in the online database by *netzspannung.org media arts & electronic culture*: http://netzspannung.org/database/130599/de [last update: 04.03.2004] (last accessed on 02.02.2015).

[19] Frischer 2008, p. vi.

[20] See 'ASPEN Movie Map' in the online database of *netzspannung.org media arts & electronic culture*: http://netzspannung.org/database/130599/de [last Update: 04.03.2004] (last accessed on 02.02.2015).

[21] Naimark 1997, here: para. 2.1 Past Moviemaps.

[22] Ibid., here: para. 2. Moviemaps.

[23] Mohl 1981, p. 2.

[24] Ibid.

[25] Naimark 2006, here part about: The Aspen Moviemap – Place Representation.

[26] Naimark 1997.

[27] Choo 2004, p. 21; Pfarr 2010, p. 13.

[28] See website of the company SGI, which has been renamed Silicon Graphics International Corp. since: http://www.sgi.com/company_info/overview.html (last accessed on 02.02.2015).

[29] Frischer et al. 2002, p. 9.

[30] Frischer 2008, p. vi. According to Frischer this was the first essay about the subject of 3D: Biek 1985, which was about the creation of 3D images by overlaying two images (see Biek 1985, p. 4). By now *CAA* stands for 'Computer Applications & Quantitative Methods in Archaeology', see Conference Proceedings since 1973, which have been published online on the website of the *CAA*: http://proceedings.caaconference.org/ (last accessed on 02.02.2015).

[31] See the project description on the website 3DVisA of the King's College, London: http://3dvisa.cch.kcl.ac.uk/project12.html [state of 12.03.2012], (last accessed on 02.02.2015).

[32] Ibid.

[33] See also the overview of the past exhibitions of the British Museum on its website: http://www.britishmuseum.org/whats_on/past_exhibitions.aspx, (last accessed on 02.02.2015) and see the project description on the website 3DVisA of the King's College, London: http://3dvisa.cch.kcl.ac.uk/project12.html [state 12.03.2012], (last accessed on 02.02.2015). Detailed information on the background and the implementation of the project can be found there and in the following essay by the archaeologist Paul Reilly: Reilly 1992, esp.: pp. 152-154.

[34] See also the project description on the website 3DVisA of the King's College, London: http://3dvisa.cch.kcl.ac.uk/project12.html [state 12.03.2012], (last accessed on 02.02.2015) and see Reilly 1992, p. 152.

[35] Reilly 1992, here: p. 152.

[36] See the project description on the website 3DVisA of the King's College, London: http://3dvisa.cch.kcl.ac.uk/project12.html [state 12.03.2012], (last accessed on 02.02.2015). Detailed information on the back-

ground and the implementation of the project can be found there and in the following essay by the archaeologist Paul Reilly: Reilly 1992, esp.: pp. 152-154.

37 See the project description on the website 3DVisA of the King's College, London: http://3dvisa.cch.kcl.ac.uk/project12.html [state 12.03.2012], (last accessed on 02.02.2015).

38 Ibid.

39 Ibid.

40 Reilly 1992, here: p. 152.

41 Ibid.

42 Frischer 2008, p. vi-vii and Arnold et al. 1989.

43 See Arnold et al. 1989, p. 147 and pp. 150-151.

44 Ibid. p. 147.

45 Reilly 1992, here: p. 165.

46 Ibid.

47 See Arnold et al. 1989, pp. 149-150.

48 Ibid. p. 150.

49 Ibid. p. 152.

50 See Arnold et al. 1989, p. 152.

51 Reilly 1992, here: p. 166.

52 See Arnold et al. 1989, p. 150 and p. 152.

53 Alkhoven 1993, p. 52.

54 For information about the creation of the 3D model see Maver 2002, p. 94.

55 Alkhoven 1993, p. 52.

56 Maver 2002, p. 95.

57 If not stated otherwise, see for the following information about the project 'Die dreidimensionale Rekonstruktion und Simulation von Cluny III': Koob 1993.

58 About the construction history of the church Cluny III see Cramer 1993, p. 14 and 16 .

59 Koob 1993, p. 58; and Grellert 2007, p. 495.

60 Cramer 1993, p. 14.

61 For information about the exhibition see the exhibition catalogue: Das Reich der Salier 1992.

62 See Stenvert 1991.

63 Stenvert 1991, p. 134.

64 Stenvert 1991, p. 134. For the following information about the state of the art of CAD programmes and the problems in art history see ibid.

65 Hersey and Freedman 1992; and Novitski 1998, p. 81. In 1978 William J. Mitchell had, together with George Stiny, noticed that Palladio's plans are based on a certain set of rules and defined stylistic elements, so that they probably could be translated into a computer algorithm (see Stiny and Mitchell 1978, esp. pp. 17-18). For information on Palladio see Frommel 2007, pp. 201-213.

66 Hersey and Freedman 1992, p. 39.

67 Seebohm 1991, p. 149; and Novitski 1998, pp. 80-83.

[68] Ibid. p. 81; and Seebohm 1991, p. 135. When Seebohm presented his study at the ACADIA in 1991, the publication by Freedman and Hersey was still in production until it was finally published as a book in 1992.

[69] Ibid. p. 165. For the following information about Seebohm's study see ibid. p. 149 and 165.

[70] Stenvert 1991, pp. 135-136

[71] Ibid. p. 136.

[72] Alkhoven 1993, pp. 91-103. If not stated otherwise, see to the following information about Alkhoven's work on the city of Heusden: Alkhoven 1993.

[73] Alkhoven 1992, p. 549. The first micro computer was developed under the name 'Micral' or 'R2E' in France by the company Realisations Études Électroniques S.A. (REE) in 1973 and was equipped with an Intel 8008 processor. It cost 1.900 US Dollar (see Allan 2001, chapter 4, p. 7).

[74] Alkhoven 1993, p. 223. For the following information about Alkhoven's work about the city of Heusden see Alkhoven 1993.

[75] Müller and Quien 1993, p. 276.

[76] Information on this by Norbert Quien, email from the 22.12.2015. A short report on the DFG project can be found in: Jäger et al. 2004. About the running time of the project see Müller and Quien 1999a, p. 2.

[77] Müller and Quien 1993, p. 272.

[78] Ibid., p. 276, p. 280, fig. 3.1, 3.2 and p. 281 fig. 4.1.

[79] Ibid., p. 276.

[80] Müller and Quien 1999a, p. 2.

[81] Ibid., p. 2.

[82] Information on the life and work of Werner Müller can be found in: Kurrer 2005 (available online on the website of ARCH+: http://www.archplus.net/home/archiv/artikel/46,3492,1,0.html, last accessed on 02.02.2015). Examples worth noting are the following related publications by Müller and Quien: Müller and Quien 1993; Müller and Quien 1999b; Müller and Quien 2005.

[83] Boland and Johnson 1996, p. 231. If not mentioned otherwise, see to the following information on Dudley Castle: Boland and Johnson 1996.

[84] For information on the development of Virtual Reality see Ronchi 2009, esp.: pp. 118-130.

[85] See to this information in the video *Virtual Tours of Dudley Castle in 1550* for the reconstruction of Dudley Castle on YouTube: http://www.youtube.com/watch?v=DVdXSmpQAYQ (last accessed on 02.02.2015).

[86] Collins et al. 1995, p. 19. If not mentioned otherwise, see to the project of the Dresden Frauenkirche: Collins et al. 1995.

[87] Ronchi 2009, p. 341.

[88] Collins et al. 1995, p. 19.

[89] Dylla et al. 2010, p. 62.

[90] For information on the project see website about *Rome Reborn*: http://romereborn.frischerconsulting.com/ [State of 1. August 2013], (last accessed on 02.02.2015).

[91] Ibid.

[92] Frischer et al. 2000, here: p. 155.

[93] See website on the project: http://romereborn.frischerconsulting.com/about.php [state from 1. August 2013], (last accessed on 02.02.2015).

[94] For this information I'd like to cordially thank Prof. Bernard Frischer. Images and videos about the early state of *Rome Reborn* can be found on the website *Digital Roman Forum*, which was created by the CVRLab of the UCLA from 2002 to 2005: http://dlib.etc.ucla.edu/projects/Forum/ (last accessed on 02.02.2015).

[95] See website on the project: http://romereborn.frischerconsulting.com/about.php [state from 1. August 2013], (last accessed on 02.02.2015).

[96] Frischer et al. 2000, part 3, 'Identification of historical and archaeological research issues'. For the following information on the project about Santa Maria Maggiore see Frischer et al. 2000, part 3.

[97] Ronald Stenvert explains in his 1991 dissertation that at this time CAD programmes run on common PCs and are also affordable for architecture firms (see Stenvert 1991, p. 99).

[98] Robert Simpson Frew, Associate Professor of the Yale School of Architecture 1977, explained in his contribution to the *Design Automation Conference 1977* (DAC'77), that there were about 108 Schools of Architecture in Northern America. According to Frew, the following universities could be classed as early centres that used and developed computer technologies in the field of architecture: MIT, *Carnegie Mellon University* in Pittsburgh, *Cornell University* in Ithaca, New York and UCLA (see Frew 1977). Only seven universities presented their current teaching offers related to CAD at the DAC'77 (see DAC77 1977, pp. 277-283).

[99] The *Berliner Symposium zur Architektur* was held for the fourth time at the *Technische Universität Berlin* in 1989. Diverse international universities presented their teaching offers and projects on CAD application (see Kernchen 1989).

[100] See website of the CAA: http://caa-international.org/about/ (last accessed on 02.02.2015). Most of the conference proceedings, which have been published since 1973, are available online on the website of the CAA: http://proceedings.caaconference.org/ (last accessed on 02.02.2015).

[101] See website of the CAA: http://caa-international.org/about/ (last accesseded on the 02.02.2015). For the information about the CAA mentioned below see ibid.

[102] See website of ACADIA: http://acadia.org/about (last accessed on 02.02.2015).

[103] See website of ACADIA: http://acadia.org/conferences (last accessed on 02.02.2015).

[104] See article on 'Education and Research in Computer Aided Architectural Design in Europe' at Wikipedia: http://en.wikipedia.org/wiki/Association_for_Education_and_Research_in_Computer_Aided_Architectural_Design_in_Europe [State: 27.01.2015, 19:04], (last accessed on 02.02.2015).

[105] For information on *eCAADe s*ee the website of the society: http://www.ecaade.org/ (last accessed on 02.02.2015) and articles about 'Education and Research in Computer Aided Architectural Design in Europe' at Wikipedia: http://en.wikipedia.org/wiki/Association_for_Education_and_Research_in_Computer_Aided_Architectural_Design_in_Europe [state: 27.01.2015, 19:04], (last accessed on 02.02.2015). Among the organisations founded later are: *CAADRIA* founded in Asia in 1996, *SIGraDi* founded in Latin America 1997 and *ASCAAD* in the Arabic-speaking world, founded in 2001 (see ibid).

[106] For information about the founding and the activities of *eCAADe* see website of the institution: http://www.ecaade.org/ (last accessed on 02.02.2015).

[107] See website of *CumInCAD*: http://cumincad.scix.net/cgi-bin/works/Home (last accessed on 02.02.2015).

[108] An outline of university research projects in the field of virtual reality in the US at the beginning of the 1990s can be found in: Paranandi and Sarawgi 2002, pp. 314-315.

[109] See website of the ESC: http://www.simcenter.org/home/ (last accessed on 02.02.2015) and Steele 2001, p. 45. About the information on the project of ESC mentioned below see Steele 2001, p. 45.

[110] Favro 2006, p. 321. Since the co-founder Bernard Frischer moved to another University in 2004, the projects of the VRLab at the *Experiential Technologies Center ETC* of the University of California are continued at Los Angeles UCLA (see: http://etc.ucla.edu/, last accessed on 02.02.2015). About the history of the CVRLab see website of the *ETC:* http://etc.ucla.edu/about/ (last accessed on 02.02.2015).

[111] See website of the *Experiential Technologies Center ETC* of the University of California at Los Angeles UCLA: http://etc.ucla.edu/about/ (last accessed on 02.02.2015).

[112] Favro 2006, p. 321.

[113] Ibid., footnote 3.

[114] See website of the *Experiential Technologies Center ETC* of the University of California at Los Angeles UCLA: http://etc.ucla.edu/about/ (last accessed on 02.02.2015).

[115] See to that the project description on the website of the *Urban Simulation Team* at the University of California at Los Angeles UCLA: http://www.ust.ucla.edu/ustweb/Projects/trajans_forum.htm (last accessed on 02.02.2015). About information mentioned below about the project on Trajan's Forum see ibid.

[116] See information about EVA International on the website of EVA Berlin: http://www.eva-berlin.de/international.html (last accessed on 02.02.2015) and website of EVA London: http://www.eva-london.org/about-eva-london (last accessed on 02.02.2015).

[117] Ibid.

[118] Ibid.

[119] See online archive of EVA Berlin: http://www.eva-berlin.de/eva-berlin/archiv.html (last accessed on 02.02.2015).

[120] See to the programme of EVA Berlin 1996 in the online archive of the conference: http://www.eva-berlin.de/eva-berlin/archiv/archiv1996.html (last accessed on 02.02.2015).

[121] See webseite about EVA Berlin: http://www.eva-berlin.de/ (last accessed on 02.02.2015).

[122] See online archive of EVA Berlin: http://www.eva-berlin.de/eva-berlin/archiv.html (last accessed on 02.02.2015).

[123] For more information about VSMM see the websites of the last two conferences: VSMM 2012 in Milan, Italy: http://www.vsmm2012.org/ (last accessed on 02.02.2015) and VSMM 2014 in Hong Kong: http://www.vsmm2014.org/ (last accessed on 02.02.2015).

Virtual Reconstructions and Building Archaeology in Bohemia

A Digital Model of the 14th-Century House U zvonu (‘Zur Glocke’ / ‘At the Sign of the Bell’) in Prague

Michael Rykl (Czech Technical University in Prague, Faculty for Architecture, Prague, Czech Republic)

The pictorial representation of spatial, architectural aspects, today called 3D modelling, has a long tradition in Czech building archaeology. In order to illustrate what historical buildings looked like in the past, isometric drawings maintained the parallel lines measurable into the depth of space. This technique was more common than perspectival depictions, which converged into a vanishing point.

Nineteenth-Century Pictorial Reconstructions

The pictorial reconstruction of a no longer extant building from the past usually starts with bird’s eye views. One of the oldest Bohemian examples is the pre-scientific ‘reconstruction’ of the shape of the Minster in Sedlec (Sedletz) at Kutná Hora (Kuttenberg) (fig. 1). A copperplate print (1824) supposedly shows the hypothetical design of the monastic complex before its destruction in the Hussite wars in 1421.[1]

It is noteworthy that the depiction of the church was complemented by relevant information about the formal architectural system of Gothic cathedrals, while the other monastic buildings and the gardens were represented in a simpler manner and in an almost Baroque or Neoclassical style, i.e. in accordance with the stylistic preference of the time. This architectural portrait, as happened in many similar cases, was aimed at local history and was not the result of professional research.

The same applies to some of the oldest illustrations in A. Sedláček’s work ‘Hrady, zámky a tvrze království Českého‘ (Castles, Palaces and Fortifications in the Kingdom of Bohemia). This very extensive and elaborate work, which was published in 15 volumes from the end of the 19th to the beginning of the 20th century, is one of the most fundamental early works of castle research in Bohemia and is still being used today as the starting point for building archaeology or for dealing with the written sources. Nonetheless, the early volumes of this work contain pre-scientific reconstruction attempts that are stylistically based on romantic inspiration.

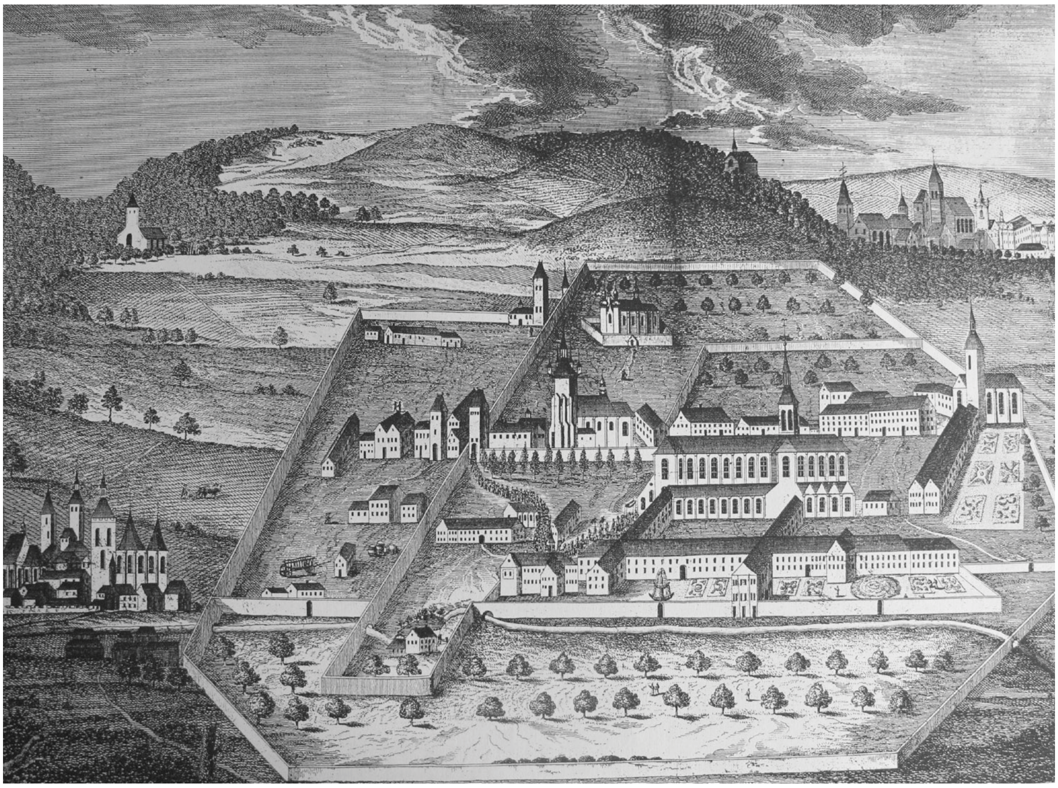


Fig. 1 Sedlec (Sedletz) Monastery at Kutná Hora (Kuttenberg) in Central Bohemia, a 'reconstruction' of the state of the monastery before its destruction in the Hussite Wars in 1421; copperplate print by F.J. Devoty from 1824; inscription above image: 'Monasterium sedlecense ante hussiticam devastationem'.

At the time, there were no walls left standing upright, only single ramparts and trenches of the little fortress Blatnik (a moated castle) in Eastern Bohemia were preserved (fig. 2 left). It was imaginatively reconstructed as a rather theatrical complex (fig. 2 right).[2]

Fig. 2 Former moated castle Blatník (Blatnik) in Eastern Bohemia; left: plan of the castle site according to F.A. Heber; right: romantic 'reconstruction' in the work of August Sedláček, 1882.

In contrast, although the reconstruction attempt of Kunětický hrad (Kunětická Hora Castle) (fig. 3 left) was also in the style of a romantic landscape painting, it still offered a relatively convincing idea of the condition of the building in the 15th century (fig. 3 right).[3]

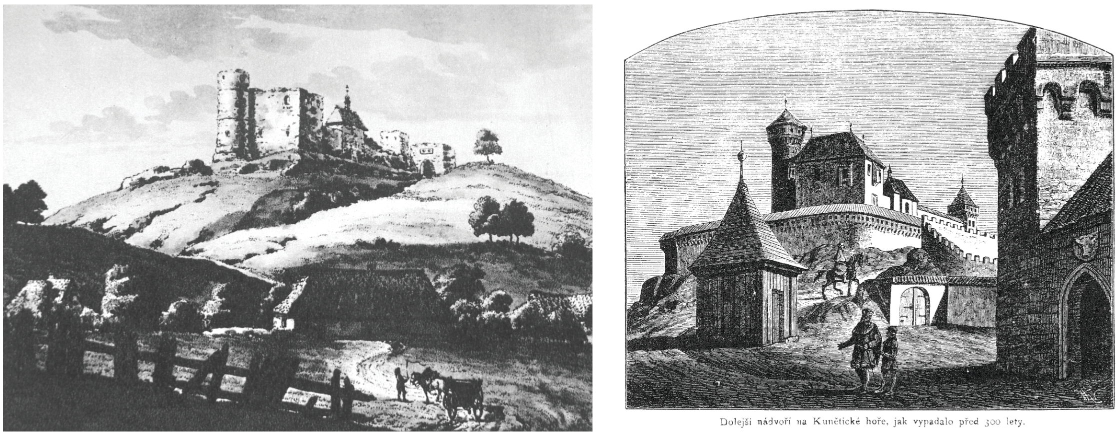


Fig. 3 Kunětický hrad (Kunětická Hora Castle) in Eastern Bohemia; left: depiction of the ruined castle at the end of the 18th century (after F.C. Wolf, 1798); right: reconstruction attempt in the work of A Sedláček, 1882.

At the time, also tangible 3D models of castles, such as the life-size model of Kokořín (Kokorschin) castle, which hosted the 1895 Ethnographic Exhibition in Prague (fig. 4).[4] It was not so much a reconstruction, as the representation of the state of the ruined castle as it stood then at its real site.

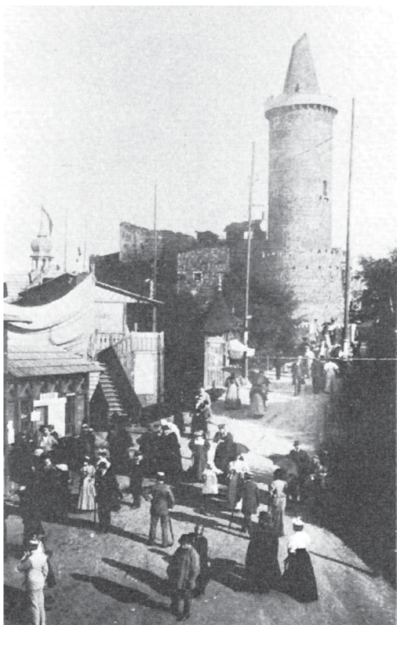


Fig. 4 Life-size model of Kokořín (Kokorschin) remains of a ruined castle at the Ethnographic Exhibition in Prague, 1895.

The life-size model of the ruin was used as a 'frame' for the dioramic presentation of a battle against the Saxon army in Northern Bohemia in 1203. Incidentally, the pavilion of the Bohemian tourist board (fig. 5) tried to look like the fictitious gatehouse of a medieval city or castle.

Fig. 5 Pavilion modelled after a medieval city gate at the same fair (photo: 1895).

Those two examples illustrate the role of medieval 'reconstructions' during the late national heritage movement in Bohemia at the turn of the 20th century. Spatial representations, in the sense of 1:1 models and perspectival images established a new and expressive medium.

The Birth of Early Building Archaeology during the First Half of the 20th Century. The Example of the St Agnes Convent in Prague

During the time between the two World Wars, the discipline of science-based building archaeology developed alongside archaeology in the young Czechoslovakian Republic. Both fields focused more closely on cultural history, art history and building conservation than on local history.[5]

A paradigm of collaboration between archaeology and building archaeology was constituted by the exploration of Prague Castle as well as by research on the St Agnes convent, built as a royal commission in ca 1230 in the Old Town of Prague.[6]

During the war, between 1940 and 1942, the detailed investigation of the convent, including the 13th-century burial place of the royal Přemyslid dynasty, was a secret expression of Czech national pride at the time of German occupation; nonetheless issues of reliability and methodology were not neglected. To the contrary – the extraordinarily elaborate documentation, including a number of isometric drawings, greatly raised the level of building archaeology at the time.

Fig. 6 Convent of St Agnes in Prague (ca 1230-1265 in four building phases); investigative campaign of ca 1940-42: Archaeology conducted by Borkovský, building archaeology by Stefan, documentation by Nezbeda et al. The former monastic church St Francis with two naves, used as a cemetery since the 18th century; isometric drawing of the fundamental structure of the building (1941) and photograph of the archaeological excavation (1940).

Along the way, it became clear that a full understanding of the fragmentary building structures would only be possible if taking into account all three dimensions. Accordingly, it was necessary to have both ground plans and sections as well as easily understandable isometric drawings conceivable in 3D (figs. 6-8). This image-based thinking was sharpened by the 'school' of Czech architectural building researchers, who were trained to consider buildings in all of their spatial dimensions and who visualized them extensively.

This special medial tradition of pictorial reconstructions in a technical draughting style was continued after the war; three-dimensional reconstruction drawings corresponding to this tradition were particularly connected to the names Menclová, Muk and Radová, well into the 1960s and 70s.

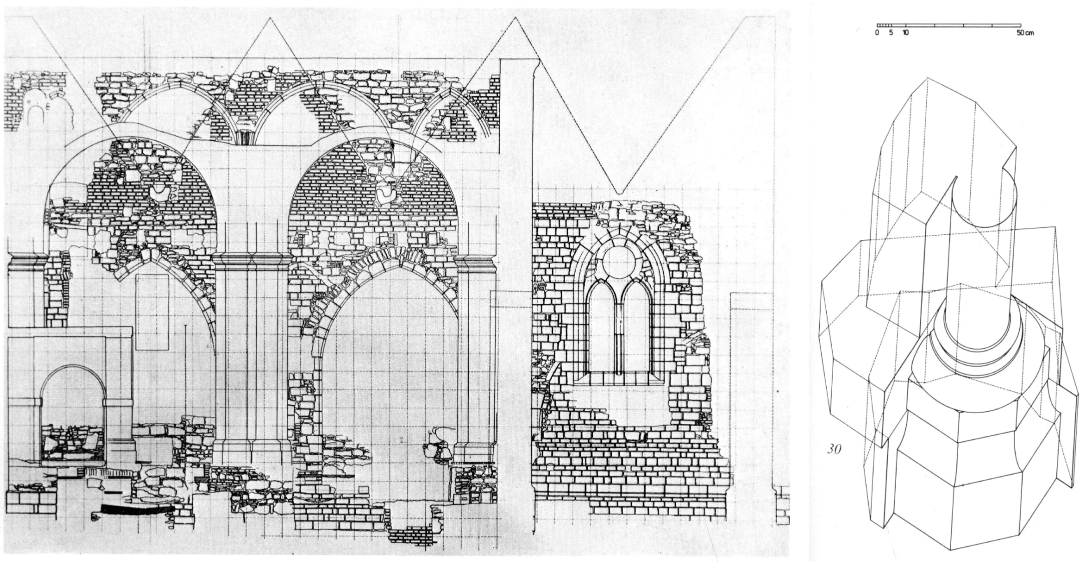


Fig. 7 Convent of St Agnes in Prague, building record of the southern wall of the church of St Francis (1960s) and isometry of the early Gothic bundles of shafts added to a newel (1945).

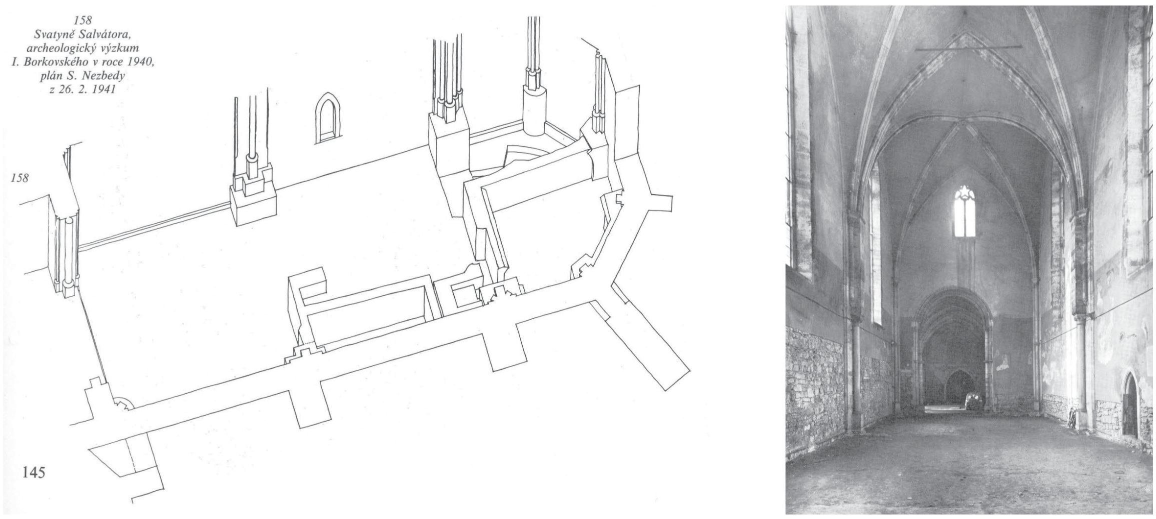


Fig. 8 Convent of St Agnes in Prague, mausoleum of the Přemyslid dynasty – St Salvator; isometry (1942) of the burial place and overview (1943), state of preservation in the 1940s.

However, even in the 1950s examples of older depictions in the style of romantic views still existed, including imaginary theories concerning the appearance of the castles of Martinice (Martinitz), Zrbek and Zvirotice (Zwirotitz), which had been archaeologically investigated.[7] The amount of so far unknown details of the buildings to be reconstructed became a central descriptive and scientific problem (fig. 9).

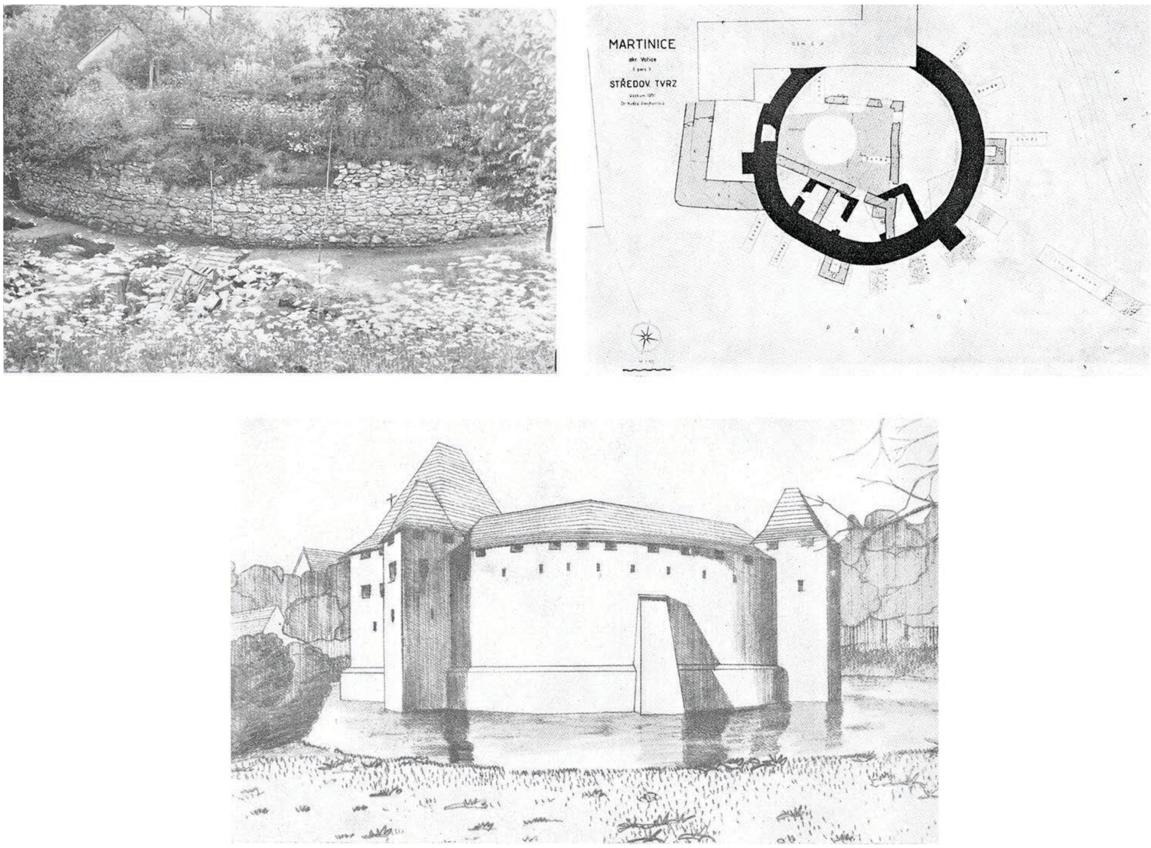


Fig. 9 Martinice (Martinitz) in Central Bohemia; state of the basic structure of the building during the archaeological excavation, ground plan and reconstruction attempt (1955).

Reconstruction Drawings by D. Menclová

The technical style of the school of architects and buildings researchers was used by D. Menclová in her 1972 work *České hrady* (Bohemian Castles).[8] While reconstructing the façades, the remaining building structure was used as a point of reference (fig. 10). Many castles were reconstructed as isometric drawings or bird's eye views; their depiction is usually based on reliable information on building structure, resulting from the research of the building's condition, as well as on spatial structures and their functions. Yet, these representations are lacking in many details and contain uncertain aspects, whose range of probabilities cannot be clearly expressed in the images.

Some reconstructions executed as tangible models (fig. 11) reached a state of appropriate clarity and simplicity while many were still beset with many uncertain details (fig. 12).

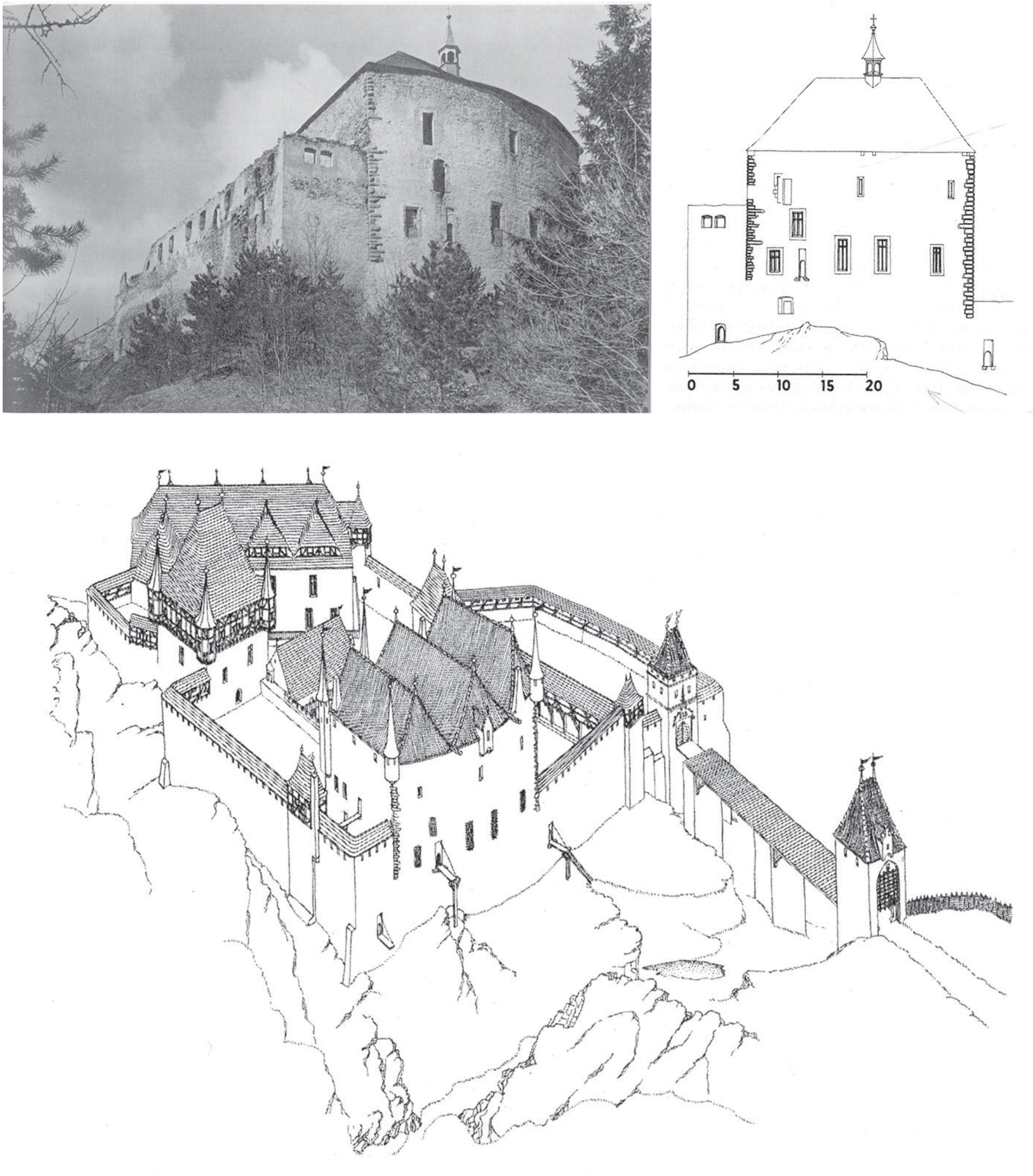
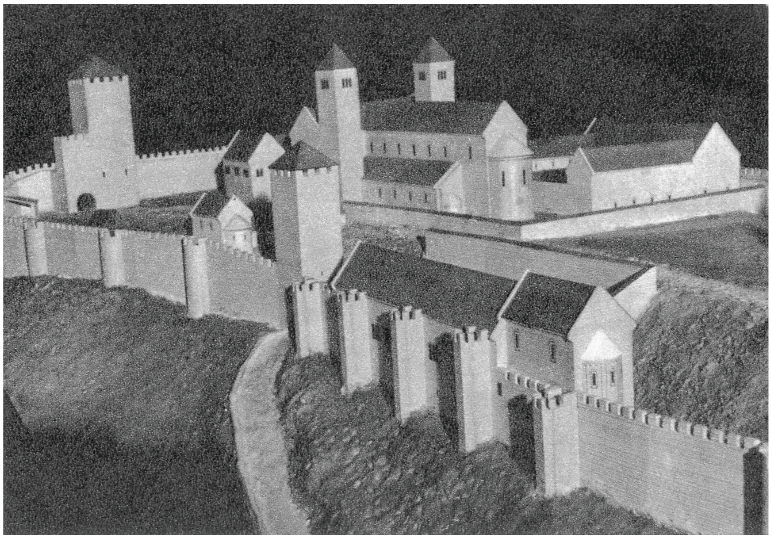


Fig. 10 Ruin of the royal Točník (Totschnik) castle, ca 1400; photo of the fundamental building structure, building survey and reconstruction from the bird's eye perspective (1972).



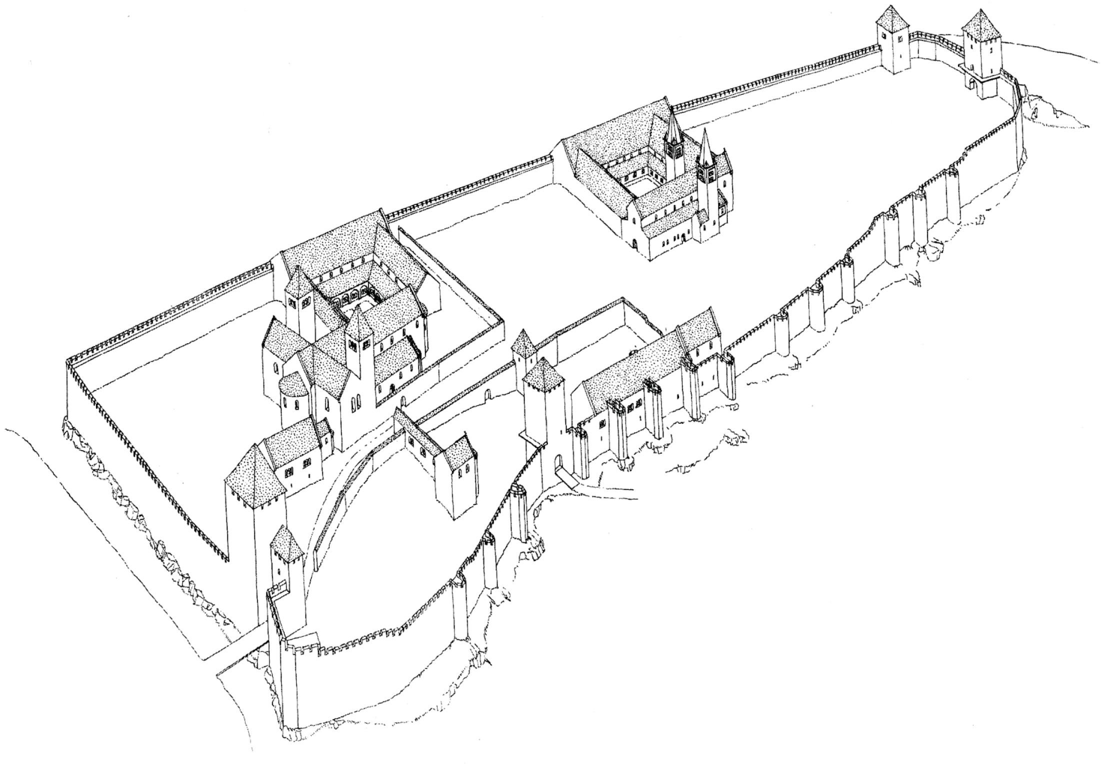


Fig. 11 Prague Castle, late 12th century; tangible model and bird's eye view (1972).

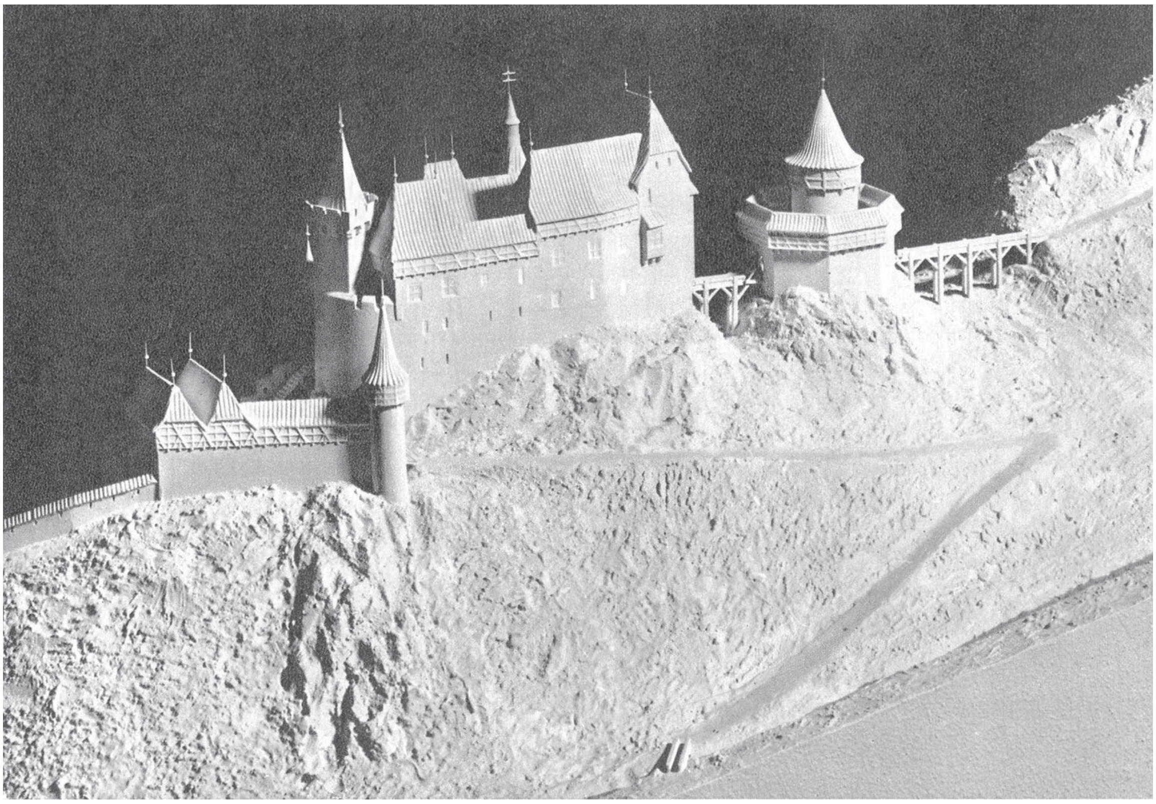


Fig. 12 Český Šternberk (Bohemian Sternberg): fortifications with ramparts from the 15th century; model by D. Menclová, 1972.

New Methods of Representation in the 1980s: P. Chotěbor

When the work on the illustrations for the first, still very limited edition of the new compendium of Bohemian castles by T. Durdik started in 1984,[9] the artist, architect and building researcher P. Chotěbor initiated a discussion about the respective reliability of different forms of reconstructive representation.

A comparison of the depictions of Okoř castle by D. Menclová and P. Chotěbor regarding style and content illustrated the most important differences between the two philosophies of representation employed: most importantly, Chotěbor omitted all detail and the focus was on the depiction of the building's scale (fig. 13).

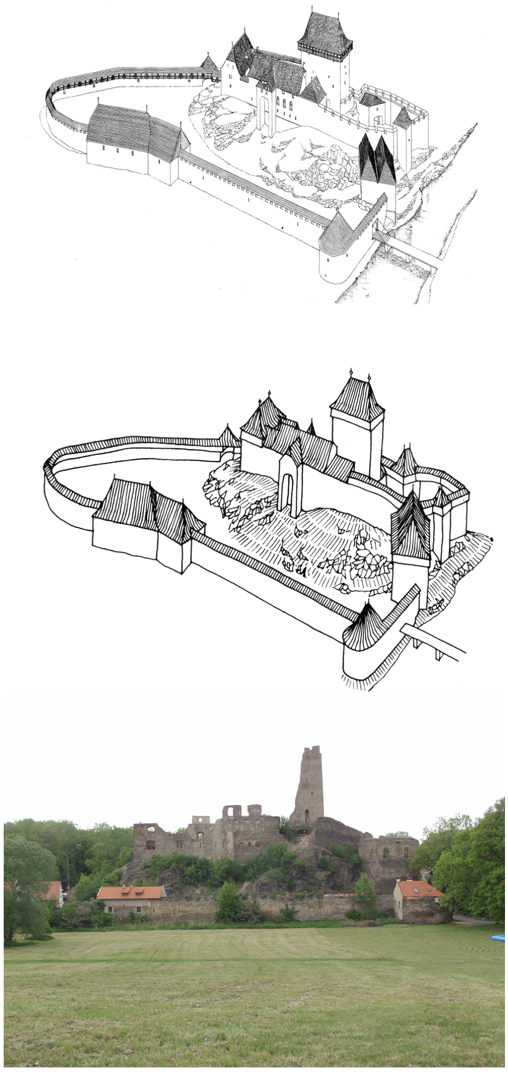


Fig. 13 Comparison of the depictions of Okoř Castle in Central Bohemia by Menclová (1972) and Durdík with Chotěbor (1984). The condition of the castle's ruin is documented in the photograph (2013).

The comparison of the possibilities, limits and risks of these different concepts of representations is easily demonstrated by using the example of Skalsko Castle (fig. 14). All that remains of the castle are the castle grounds with a clearly visible moat and a few remnants of the walls. Chotěbor exemplified diverse degrees of detail, even in the less detailed volumetric model he worked with alternatives, since too little information on the castle's ruin was available without an in-depth archaeological investigation.[10]

In addition, Chotěbor worked with different kinds of tangible models, in particular those made from clay (fig. 15). Because of his choice of material, the details that could not be clarified had to be left off.

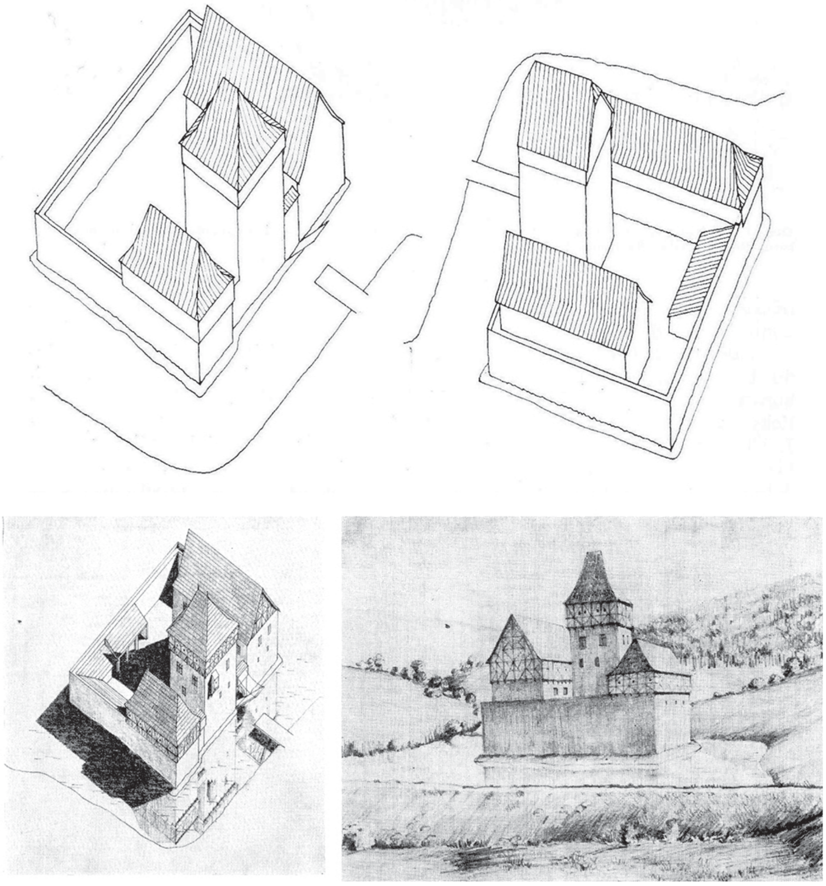


Fig. 14 Ruin of Skalsko Castle in Central Bohemia, reconstruction attempts without the benefit of archaeological research; volumetric reconstruction depicting alternatives compared to many uncertain details (after P. Chotěbor, 1987).

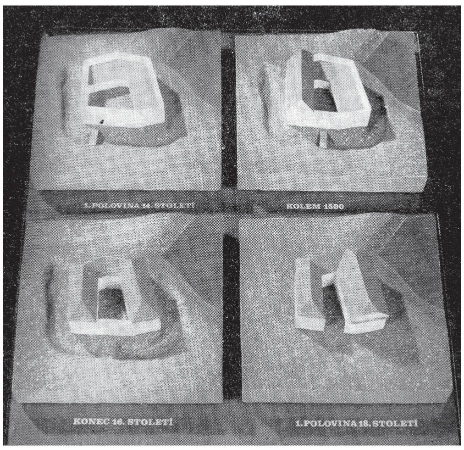
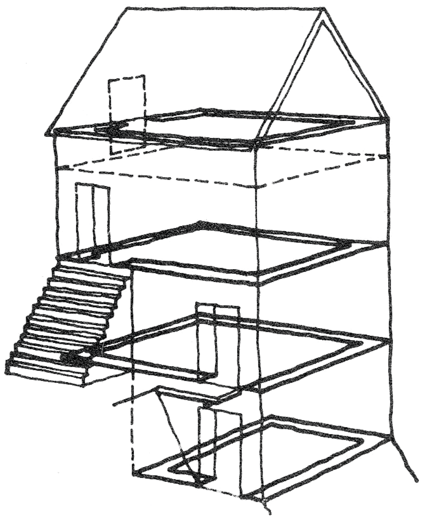


Fig. 15 Reconstruction of Dřevčice Castle in Central Bohemia in four building phases; clay model by P. Chotěbor, 1987.

The emphasis of the less detailed volumetric reconstructions modelled on Chotěbor's example were accepted as a standard in Czech building archaeology ever since, especially for the representation of former building phases of which very little information is available, i.e. in the case of ruined castles.

Visualization of the Interior Room Structures – M. Radová, 1972

Another line of tradition needs to be introduced here: ever since the 1970s, the archaeologist M. Radová[11] and her doctoral student J. Škabrada[12] had worked with simpler, 'transparent' isometric drawings. These not only meant to depict the former outward appearance, but were also supposed to offer a way to explore the building's interior spatial structure. As a result diverse reconstruction attempts of the staircase (fig. 16) and of the vertical development of the building structure were executed. This tradition of pictorial 3D representations is rooted in a school of architectural thinking that always considers a building as a 3D object (fig. 17).



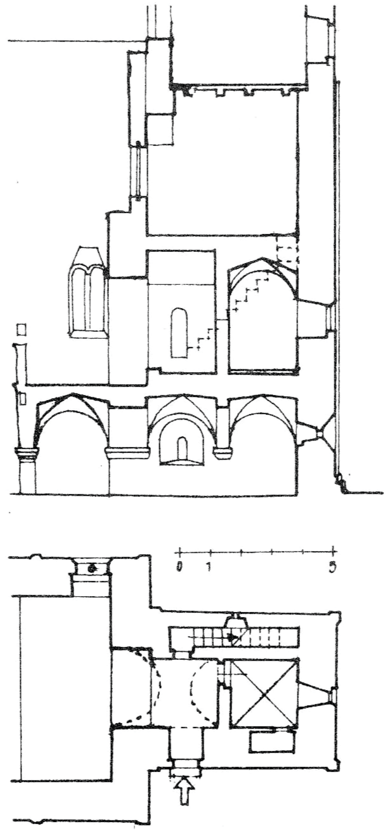


Fig. 16 Vertical communications and '3D' deliberations by M. Radová, 1972
Left: the house in Mergoscia (Tessin) in Switzerland, sketch of the motion analysis
Right: Vroutek (Rudig) in North-western Bohemia, spatial situation of the stairs in the Romanesque church.

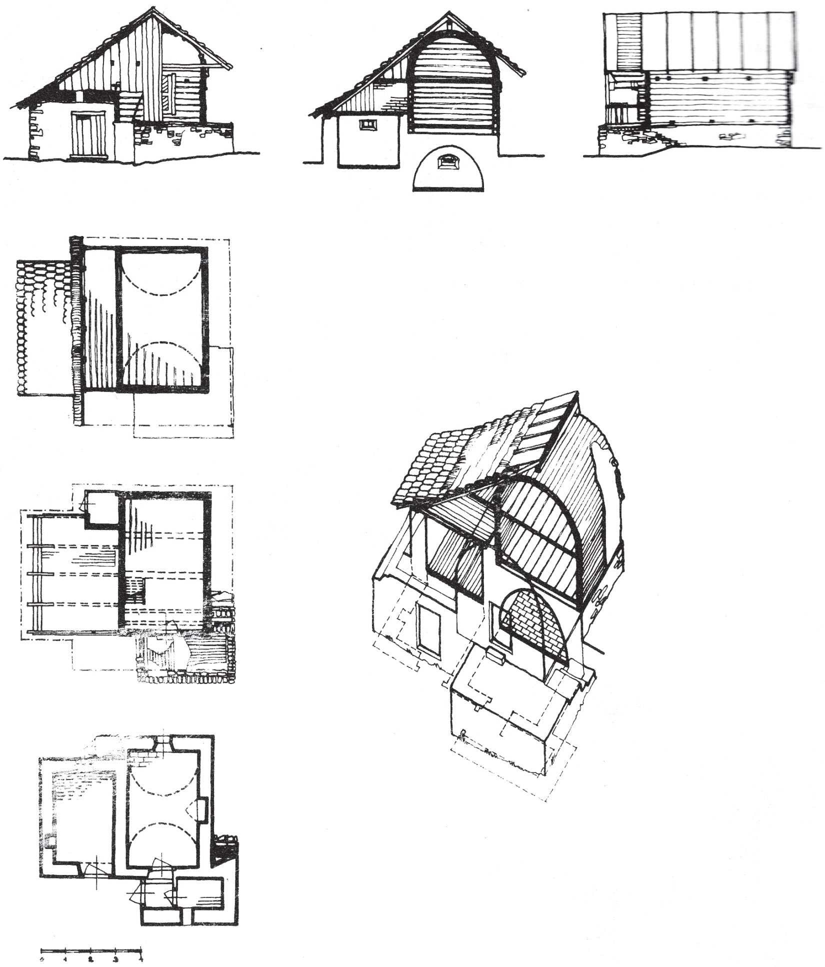


Fig. 17 Spatial situation in the attic of the granary in Dolany (Dolan) in Western Bohemia (dated to 1807); ground plan and isometric drawings, J. Škabrada 1972.

The Present: from Hand-drawn Images to Computer Aided Design (CAD)

What is typical for the current situation are attempts to incorporate the abovementioned pictorial methods of building archaeology into digital models via CAD. One example is the digital reconstruction of the church in Starý Plzenec by M. Hauserová and O. Malina (fig. 18). Although this research was presented at a conference in 2008,[13] it has remained unpublished.

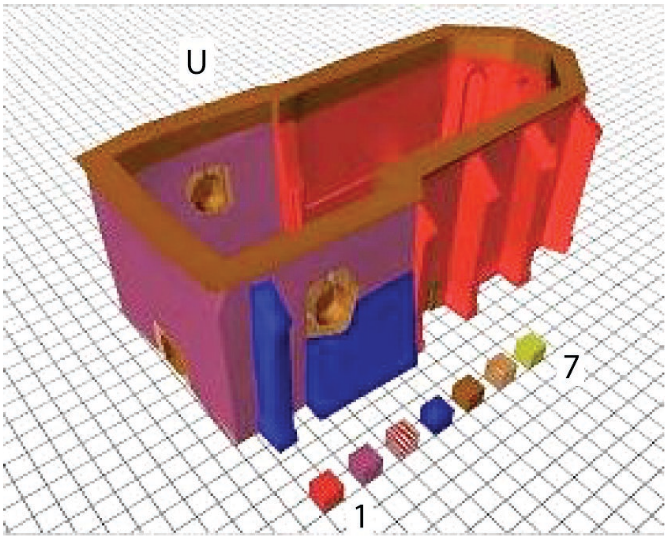
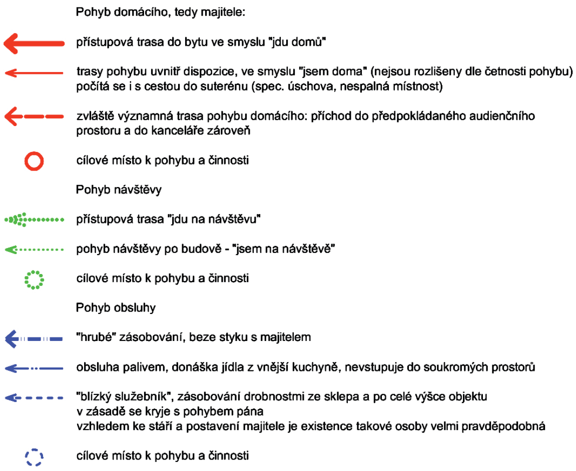


Fig. 18 Starý Plzenec in Western Bohemia, municipal church (St John Baptist); building archaeology entered in a 3D model (after M. Hauserová and O. Malina 2008).
U – Irregularity in shape is in accordance with the ruins of the Romanesque church.
1 – High Gothic
2 – Late Gothic I
3 – Late Gothic II
4 – Renaissance
5 – Baroque I
6 – Baroque II
7 – Neoclassicist

The communication and functions within the building are an important subject of research in all European contexts. The Episcopal castle Litovice (Litowitz)[14] (fig. 19) may serve as an example for diverse types of layout of rooms distributed over several floors and how this distribution changed over time. The graphical diagrams may depict different qualities of this use of space and of the movement of people through the building: the castle owner in two areas – 'at home' and 'on the way home'; the visitor – visiting or visiting inside the house, arranged according to hierarchy and etiquette; finally, the servants, according to their rank, are envisaged as they tend to the fireplaces, dinner table and storage rooms.

This depiction in a simple isometric drawing offers the necessary clarity, and thus makes a review of theories and deliberations possible.



Red: Movement of the owner
1 – Line of entrance on the way home
2 – Lines of movement when at home
3 – Particularly important line: from the apartment into the reception room (which probably also served as a chancellery at the same time)
4 – Goals of movement and activity (rooms with various functions)

Green: Movements of the close, familiar visitor
5 – Lines of entrance when coming for a visit
6 – Lines of movement when there for a visit
7 – Goals of movement (rooms with various functions)

Blue: Movement of maintenance, sorted by hierarchy
8 – Delivery into the storage rooms in the basement and ground floor
9 – Delivery of food from the adjacent kitchen building and tending to the fireplaces with firewood
10 – Delivery of trifles, full rights of entrance – one companion, the valet
11 – Goals of movement and activity

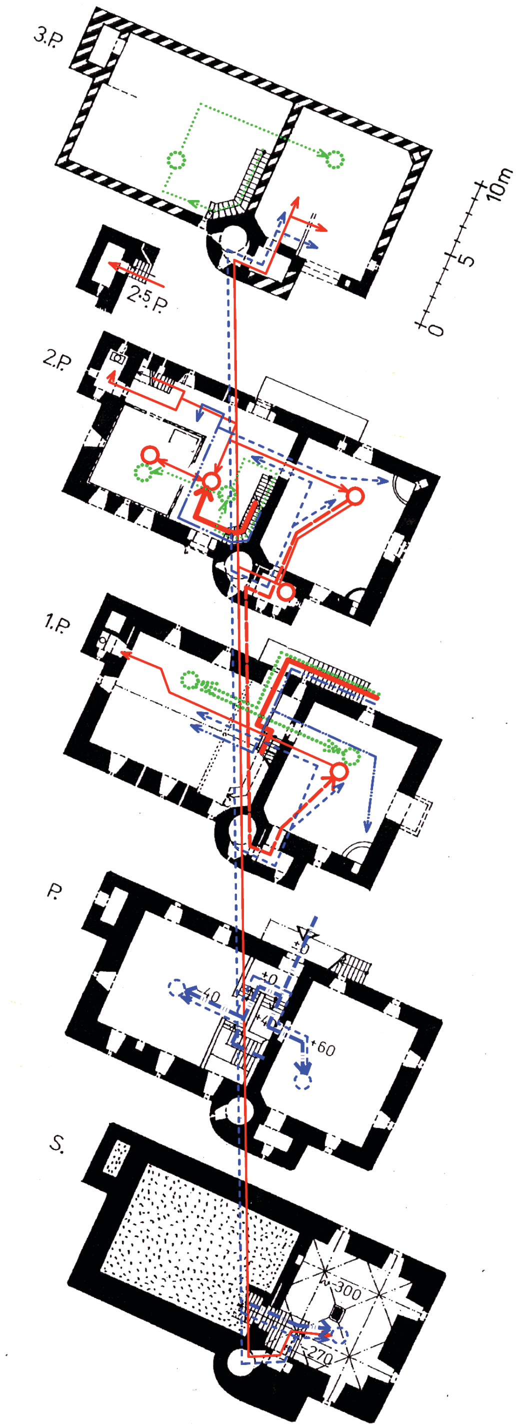


Fig. 19 Litovice (Litowitz), episcopal castle at Prague, functional scheme from the time of construction (1335 according to dendrochronology); building archaeology M. Rykl, 1995 and 2000, graphical assistance M. Fischerová, 2010.

If detailed building archaeology makes this process possible by means of documentation and evaluation, an isometric drawing of the main floor may also be considered for this purpose, in particular when it offers an appropriate amount of details. This assumption is confirmed, for example, at the town houses no. 151 (fig. 20) and no. 237 in the Old Town of Prague.[15]

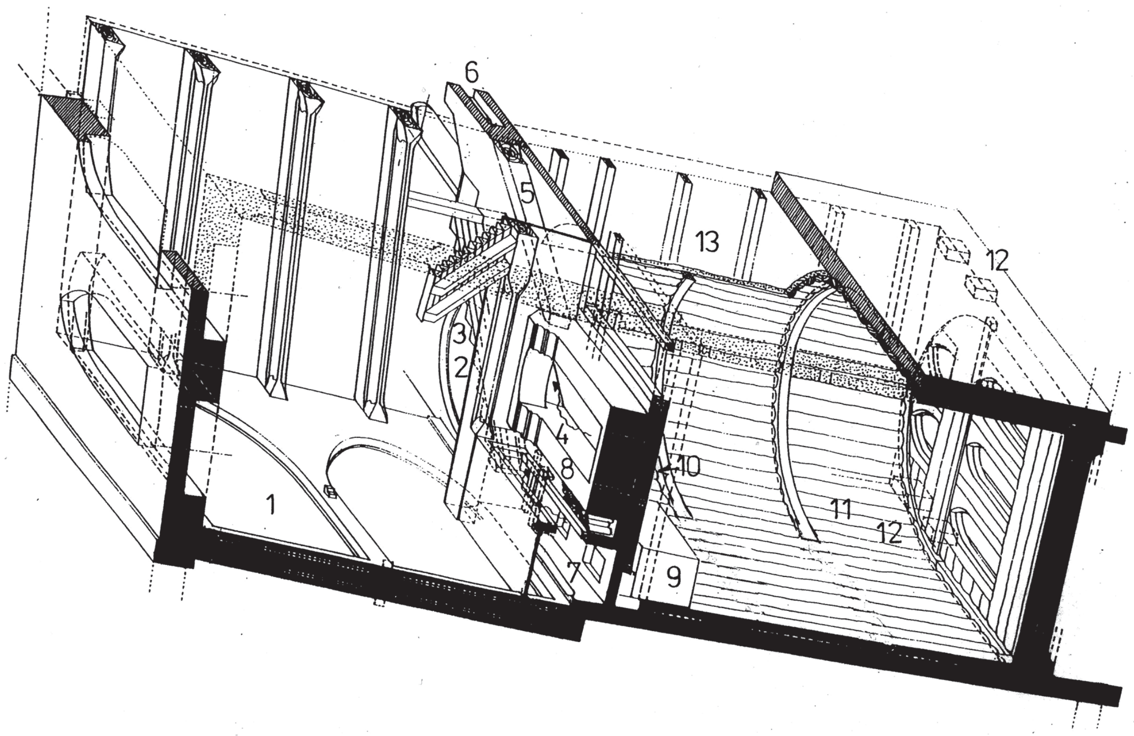


Fig. 20 House no. 151 in the Old Town of Prague, isometric drawing of the main floor – 1st floor building archaeology M. Rykl, graphical assistance D. Dobeš, 2003.

The uncertain details are drawn in broken lines (fig. 21 left). Even a small amount of details datable to the time of construction leads to a volumetric model of the ground floor and mezzanine (fig. 21 right).

The 3D representation of the group of houses in the Old Town of Prague served two functions – both as a means of evaluation and as a clear presentation – and it depicted the structure of three houses combined.[16] An analysis of the borders between the buildings led to the discovery that, surprisingly, these houses had been constructed from contiguous walls and ceilings (fig. 22).

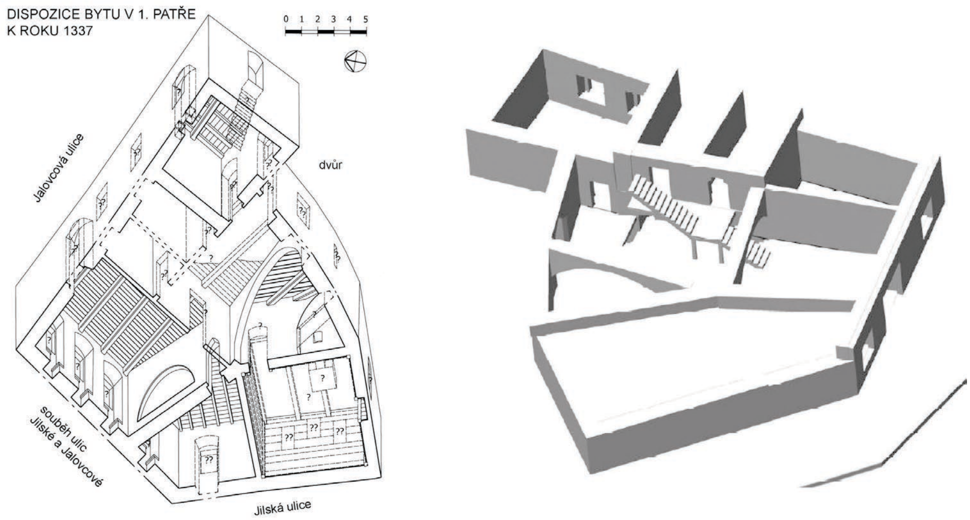


Fig. 21 House no. 234 in the Old Town of Prague; building archaeology by M. Rykl and J. Beránek.
Reconstruction of the appearance at the time of construction (1337 according to dendrochronology).
Left: isometric drawing of the main apartment on the 1st floor; graphical assistance (AutoCAD) K. Knotová
Right: ground floor and living space in the mezzanine; computer model J. Vašek, 2005.

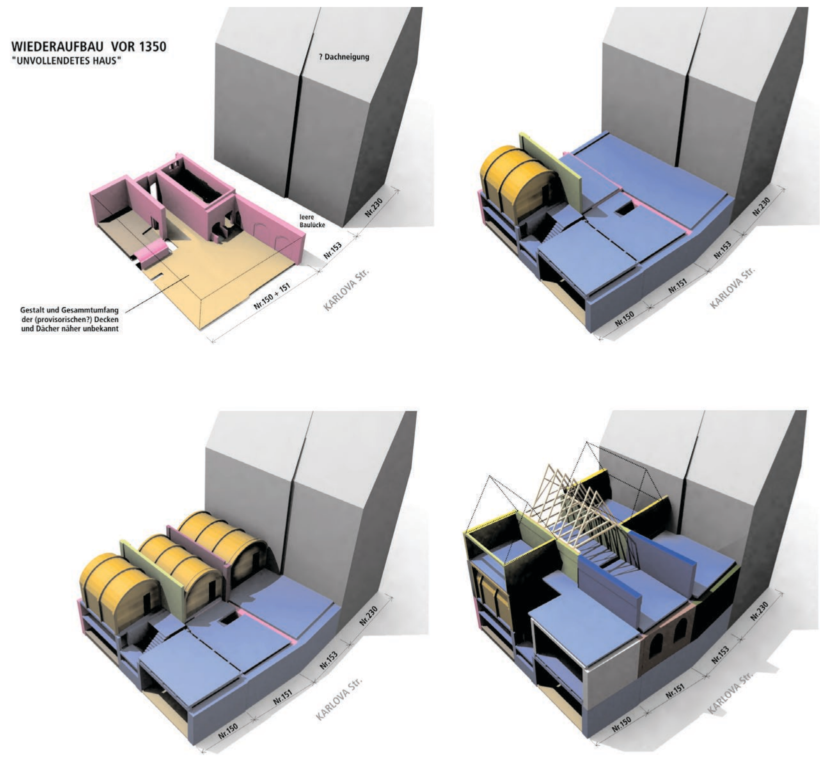


Fig. 22 Setup of the group of houses no. 151-3 in the Old Town of Prague, 1352 dendrochronology,
selection of 20 sections; building archaeology M. Rykl, 3D computer model J. Mezera (2005).

Using P. Chotěbor's method as a starting point, there are now new possibilities in the portrayal of uncertain detail in the reconstruction of buildings – in traditional graphics by using broken or dotted lines, for example, which signify a different level in hierarchy, and in digital models with the help of transparent components. Malešov Castle is a case in point (fig. 23).

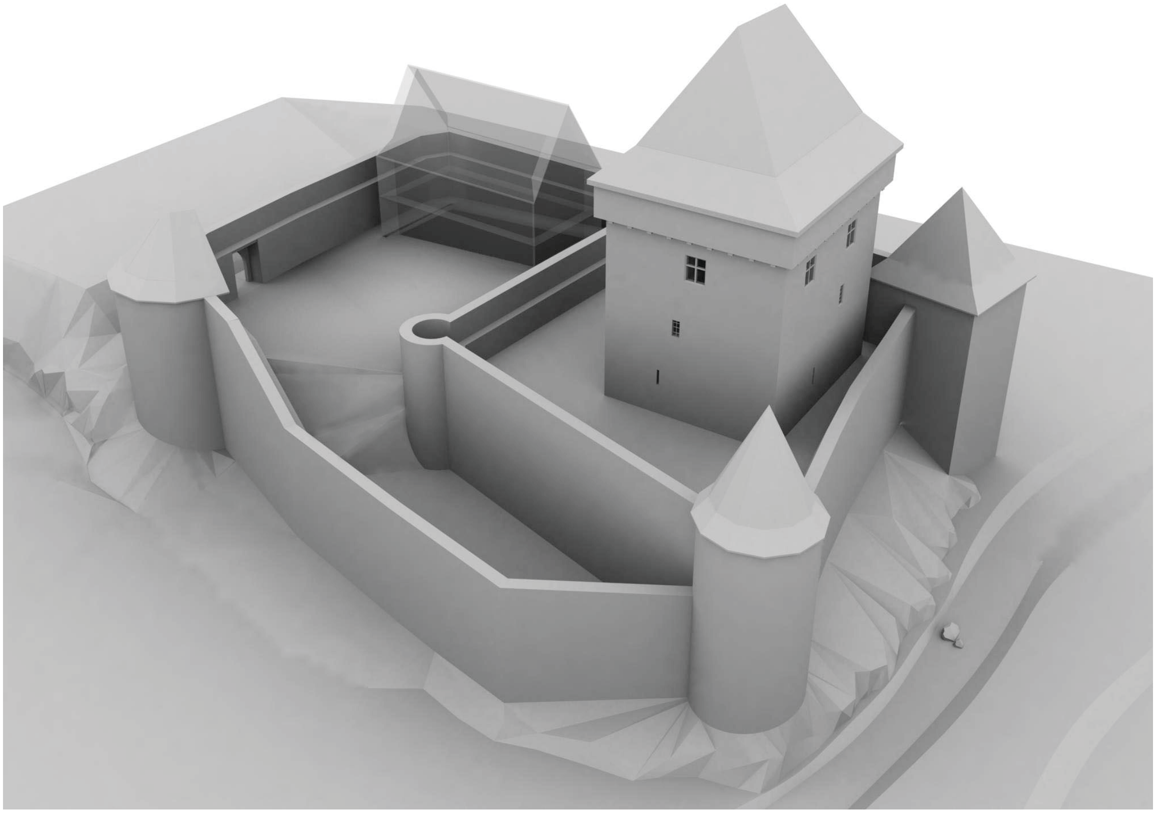


Fig. 23 Malešov (Maleschau) in Central Bohemia, reconstruction of its late Gothic appearance. Uncertain elements are depicted transparently. Building archaeology M. Rykl and M. Semerád, computer model V. Hájek 2009.

Recently elaborate, interactive or cinematic digital models of several Bohemian castles have been created. There is a model of Křivoklát (Pürglitz) castle,[17] for which the previous research by T. Durdik was summarized and adapted (fig. 24). A digital model with the option to do a virtual tour through and around Český Krumlov (Krumau) Castle was created and published by Z. Gersdorfová. In the subsequent building phases depicted, differences in the level of detail exist, which correspond to the available information regarding the structure of the building.

During these phases of construction diverse levels of detail were employed (fig. 25). By using the model, the author also verified certain paradigms regarding the elevations.[18] Therefore, the digital 3D model acts not only as a clearly arranged and attractive visualization, but also as a way of testing the reconstruction and our understanding of the spatial situation.

Fig. 24 The royal Křivoklát (Pürglitz) castle, computer model of its appearance in the 13th century by T. Durdík 2007, interactive computer model M. Menenga (2007).

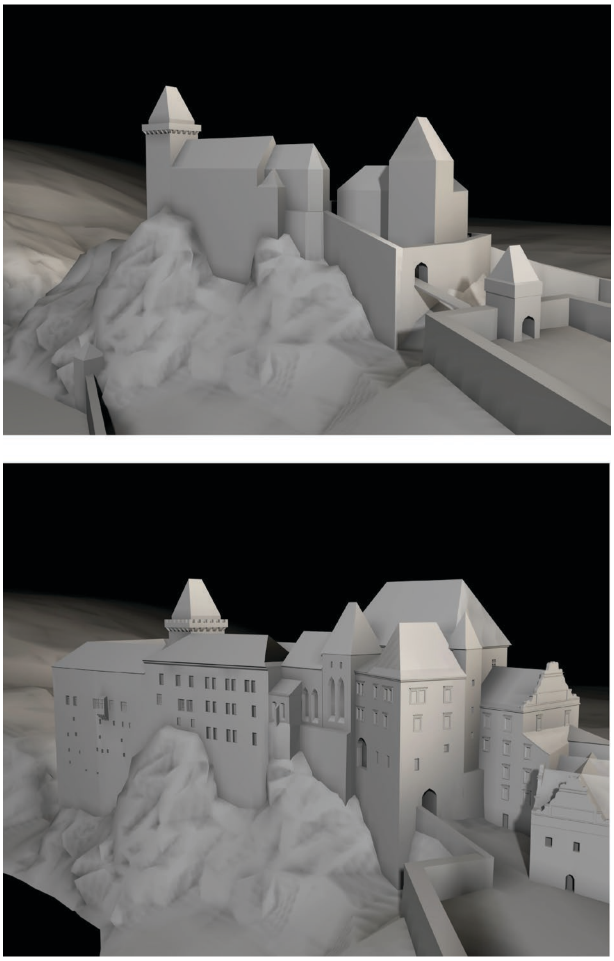


Fig. 25 The castle in Český Krumlov (Krumau), construction phase in the first third of the 15th century and again around 1600; computer model Z. Gersdorfová, published in 2010.

In conclusion it should be recognized that no model is made solely for its own sake, but mostly as a tool for research. And, sometimes the simple but clear hand drawings can be sufficiently expressive and more economical than a 3D computer graphic. In particular in those cases, in which the storeys continue on the same level, the depiction in the form of layered floor plans may be more adequate. The real and complete 3D dimensional representation, on the other hand, can be important to unravel and assess more complex forms of spatial and constructive structures – in particular when there is only a part of the actual building left.

Example: House U zvonu at the Old Market in the Old Town of Prague

In conclusion a tour through the residential tower of the house U zvonu (at the sign of the bell) in Prague shall be presented (fig. 26). This complex was built at the beginning of the 14th century as the city residence of the royal couple, using an older fabric of the palace's wings,[19] while the tower was newly built without using newer building materials.[20]

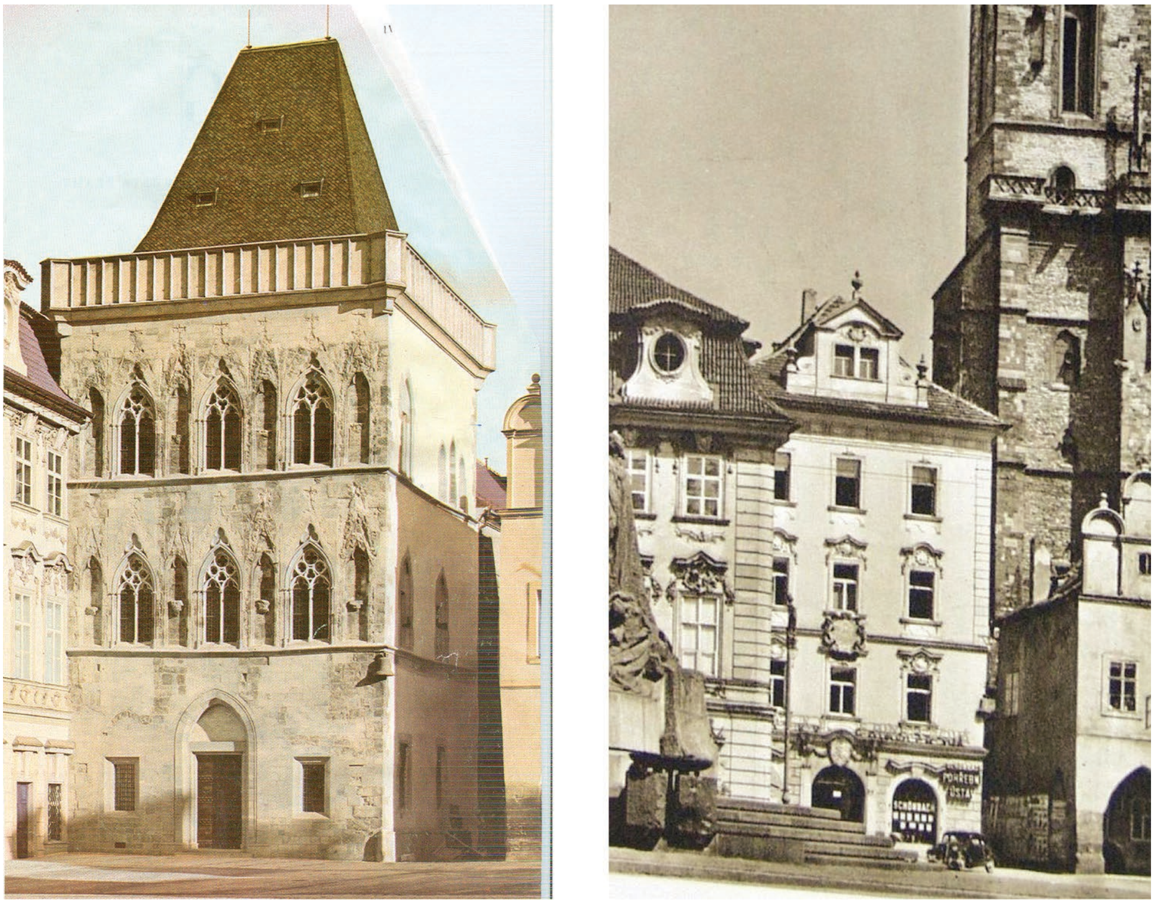


Fig. 26 Prague, Old Town, house no. 607, U zvonu, current state (left, photo from 2010) and appearance before the restoration in the Gothic style in the 1970s and 80s (right, photo published in 1955).

The building archaeology on the house was mostly conducted in the 1970s and 80s (fig. 27), before and during the real life reconstruction. But several features were misinterpreted or overlooked at the time.

The current re-evaluation in the building archaeology resulted in a changed perspective on the spatial structures in the second floor of the residential tower, in the basement and at the northern portals giving access to the spiral staircase.

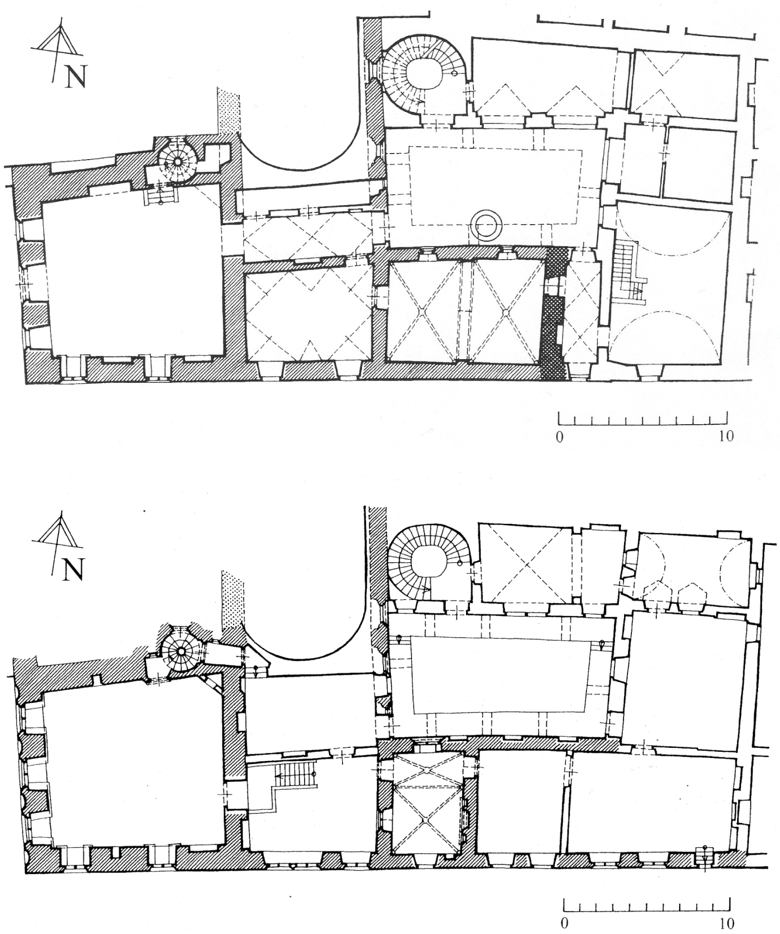


Fig. 27 Prague, house U zvonu, floor plan after J. Mayer and K. Benešovská (1971). In the intersection between the tower and the wing there is the spiral staircase, which connects all levels from the ground floor to the attic. Interpretation of the northern portals providing access to the staircase in figures 28 and 29.

For the thoughts focused on the northern portals leading to the staircase, the main method of research consisted of a survey of the elevation, using a 'table of elevations' (fig. 28). This table is a simple and clear means of inspecting the 'third dimension'.

The three rectangular portals stacked on top of each other and the distance between the portals do not correspond to a storey, neither in the tower nor in the wings.

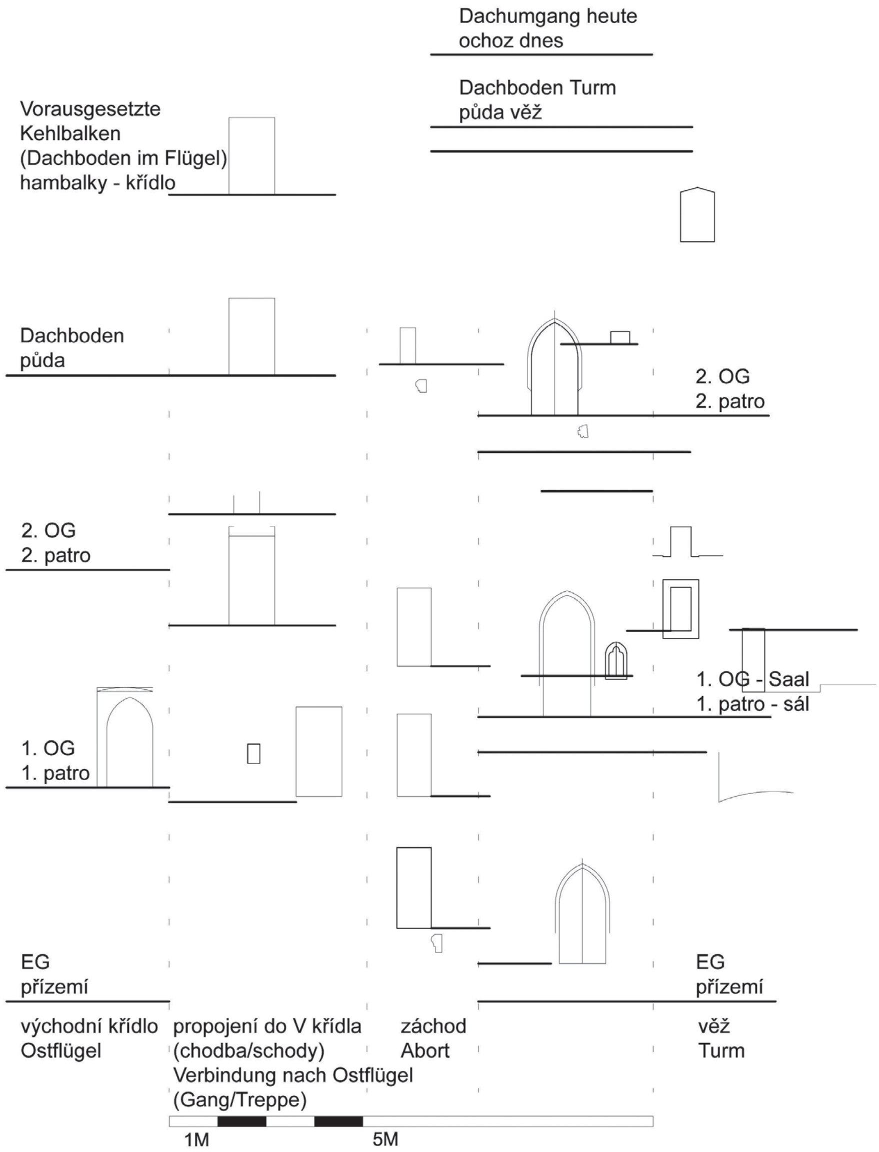


Fig. 28 Prague, house U zvonu. The table of elevations is a very clearly laid-out technique in 'three-dimensional' building archaeology. The situation surrounding the spiral staircase with three rectangular portals on top of each other can be seen in the middle of the table (2010).

Considering the spatial situation and the elevations, it was assumed that there might have been a guarderobe chute in the corner between the tower and the western wing, with three guarderobes arranged on top of each other (figs. 29-30). The room on the second floor of the tower is therefore interpreted as an apartment with a triple vaulted parlour[21] (figs. 31-33). Comparable examples of such parlours or similar rooms with a heating system (Stuben) are frequently mentioned in German literature.[22]

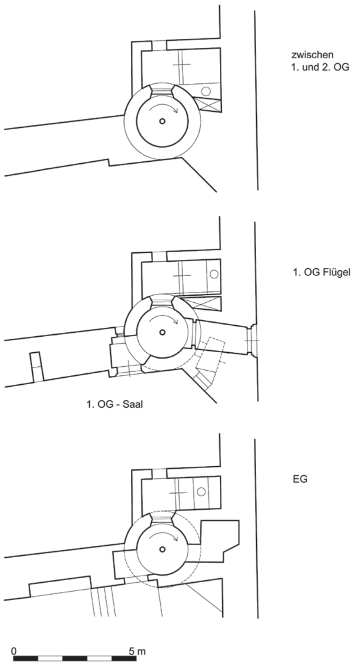


Fig. 29a Attempt to reconstruct the situation next to the spiral staircase. The three portals (passages without door leaf) lead into the antechamber of the guarderobe. The antechamber allows for minimal natural illumination of the stairs. Building archaeology M. Rykl, computer aid with the drawing (AutoCAD) V. Fanta, 2012.

Fig. 29b Rectangular portal between ground floor and first floor, the same as fig. 28 and 29c (2010).

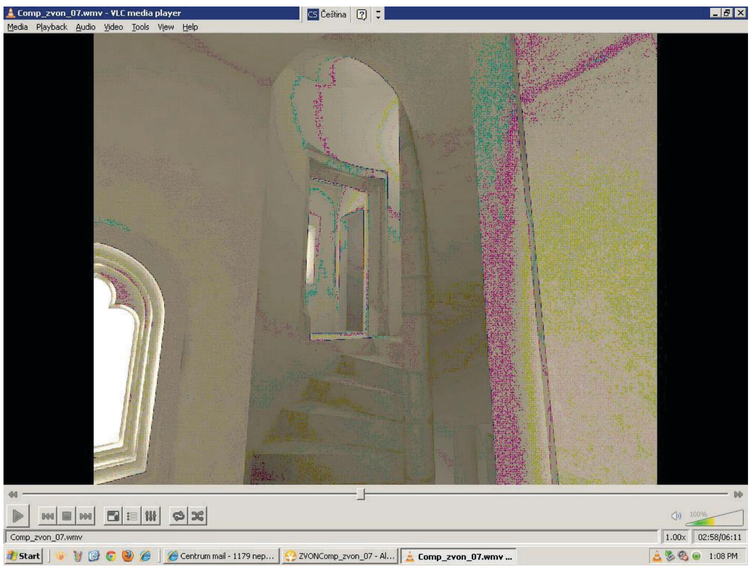


Fig. 29c Computer reconstruction of the surroundings of the spiral staircase. Situation at the elevation level of the first floor of the tower, view towards the stairs, antechamber and guarderobe. The lighting conditions are clearly visible and vital. A video still from the virtual tour (computer graphic: V. Dvořák 2010).

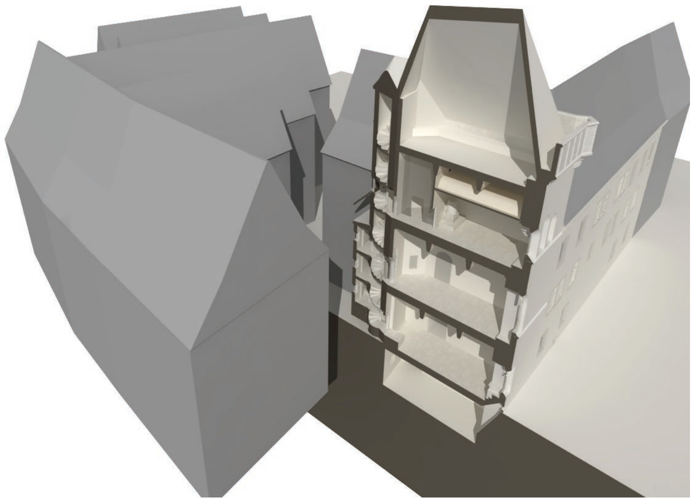


Fig. 30 Section through the tower, the spiral staircase and the guarderobes. In the second floor of the tower, there is a section through the entrance hall and through the parlour with a reconstructed hearth in the corner. Additional buildings in the complex are depicted solely as empty volume. A video still from the virtual tour (computer graphic: V. Dvořák 2010).

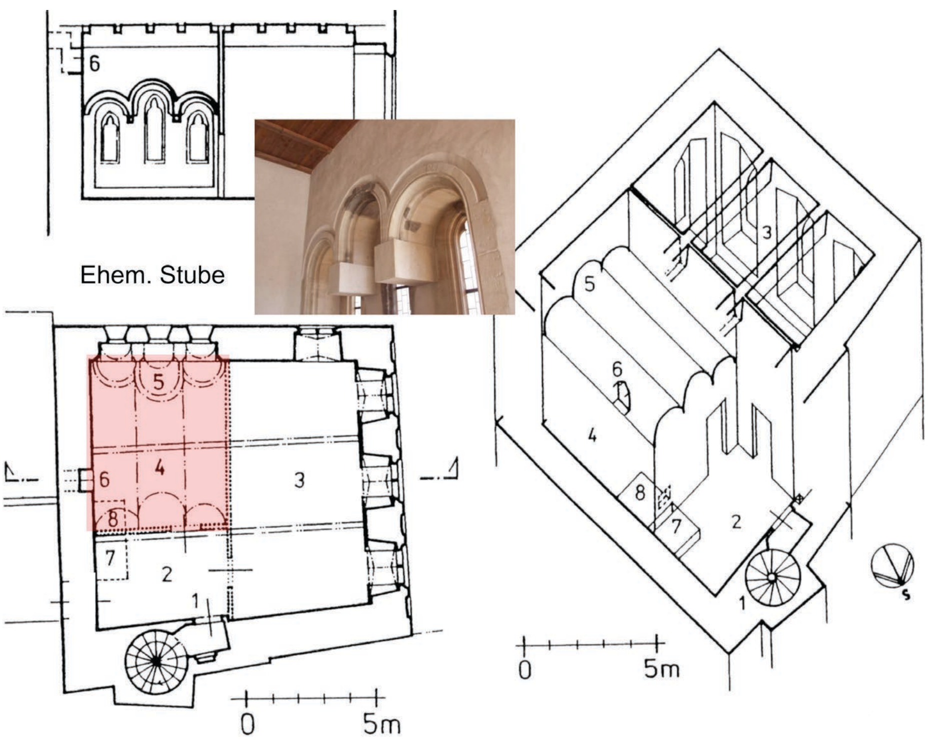


Fig. 31 Ground plan of the 2nd floor of the tower. The former parlour is highlighted in red (8 is the hearth). Building archaeology M. Rykl and J. Škabrada 1996, drawing M. Rykl. View toward the set of windows with the triple arch in the foreground.

Fig. 32 Comparable room with richly carved wooden ceiling with triple arch.
Left: Heilsbronn monastery in Franconia, abbot's chapel 1400
Right: detail of the ceiling joist in Heilsbronn (drawing: M. Rykl 1997).

For the exhibition in 2010 a digital model of the house U zvonu was created,[23] which took these new findings into account. One thing should be noted regarding the credibility of this model: after a previously published discussion about the layout of the rooms on the second floor,[24] architectural elements that had neither been preserved nor analysed were nonetheless depicted as 'full graphics'. The same applied to the guarderobes next to the staircase. In other cases, the issue of the hypothetical positioning and shape is graphically and verbally broached in the current digital images (like fig. 23).

Fig. 33 The second floor, view from the staircase through the little entrance hall into the triple-vaulted parlour (left) and into the living room to the right. The precise shape of the former wooden separating walls is unknown. Taken from the virtual tour (computer: V. Dvořák 2010).

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Illustrations

Fig. 1 Copperplate print by Josef František Karel Devoty from 1824 (Devoty 1824, p. 90).

Fig. 2 Left: plan of the castle site according to F.A. Heber, cit. in: Durdik 1999, p. 68. Right: romantic 'reconstruction' in the work of August Sedláček, 1882, cf. Sedláček 1882, p. 60.

Fig. 3 Left: depiction of the castle ruin at the end of the 18th century (after F.C. Wolf, 1798, cit. in: Menclová 1972, II, p. 499). Right: reconstruction attempt in the work of August Sedláček, 1882, cf. Sedláček 1882, p. 59.

Fig. 4, 5 Photographs in the collection of the Museum of Artistry (Uměleckoprůmyslové museum) in Prague, cit. in: Vlček 1986, p. 85.

Fig. 6 Copied from Soukupová 1989, p. 25 and 26. Photo from 1940, isometric drawing by S. Nezbeda 1941.

Fig. 7 Copied from Soukupová 1989, p. 57 and 59. Left: by J. Hyzler, 1960s; right: by S. Nezbeda, 1945.

Fig. 8 Copied from Soukupová 1989, p. 145 and 150. Left: by S. Nezbeda in 1942; right: 1943.

Fig. 9 Reichertová 1955, pp. 174-176.

Fig. 10 Menclová 1972, II, p. 159, 166 and 167.

Fig. 11 Menclová 1972, I., p. 71 and 79.

Fig. 12 Menclová 1972, II, p. 316.

Fig. 13 Top: Menclová 1972, I, p. 411; middle: Durdík/Chotěbor 1984, p. 115, bottom: photo by M. Rykl in 2013.

Fig. 14 Chotěbor 1987, pp. 325-327.

Fig. 15 Chotěbor 1987, p. 324.

Fig. 16 Radová 1972 (left: p. 108; right: p. 34).

Fig. 17 Škabrada 1972.

Fig. 18 After Milena Hauserová and Ondřej Malina 2008. With the kind permission of the authors.

Fig. 19 Building archaeology Michael Rykl, 1995 and 2000, (Rykl 2002), graphic assistance M. Fischerová, 2010.

Fig. 20 Building archaeology Michael Rykl, graphic assistance D. Dobeš, 2003.

Fig. 21 Building archaeology by Michael Rykl and Jan Beránek (Rykl/Beránek 2006). Left: graphic assistance (AutoCAD) K. Knotová. Right: computer model J. Vašek, 2005.

Fig. 22 Building archaeology Michael Rykl, 3D computer model J. Mezera, 2005.

Fig. 23 Building archaeology Michael Rykl and M. Semerád, computer model V. Hájek 2009.

Fig. 24 Computer model of the state in the 13th century by Tomáš Durdík 2007. Interactive computer model M. Menenga 2007.

Fig. 25 Computer model Zlata Gersdorfová, published in 2010, cf. Gersdorfová 2010.

Fig. 26 Left: photo from 2010; right: František/Kostka 1955, fig.20.

Fig. 27 Prague, house U zvonu, floor plan after Josef Mayer and Klára Benešovská, (Mayer 1971).

Fig. 28 Table of elevations by Michael Rykl in 2010.

Fig. 29a Building archaeology Michael Rykl, computer aid with the drawing (AutoCAD) V. Fanta, 2012.

Fig. 29b Photo by Michael Rykl 2010.

Fig. 29c Computer graphic: V. Dvořák 2010.

Fig. 30 Computer graphic: V. Dvořák 2010.

Fig. 31 Building archaeology Michael Rykl and Jiří Škabrada 1996 (cf. Škabrada/Rykl 1996, pp. 12-16), drawing Michael Rykl.

Fig. 32 Left: photo copied from: Schröttel/Haußmann 1994, like fig. 22. Right: drawing: Michael Rykl 1997).

Fig. 33 Computer graphic: V. Dvořák 2010.

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1 Devoty 1824, p. 90.

2 Sedláček 1882, p. 60; Durdík 1999, p. 68.

3 August Gottlieb Meissner, Historisch-malerische Darstellungen aus Böhmen nebst XIV illuminierte Kupfertafeln nach Zeichnungen von F.C. Wolf, Prague 1798, cit. in: Menclová 1972, II, p. 499; Sedláček 1882, p. 59.

4 Photographs in the collection of the Museum of Artistry (Uměleckoprůmyslové museum) in Prague, cit. in: Vlček 1986, p. 85.

[5] One of the best at the time was the architect Kamil Hilbert. His research illustrates the foundations of the correct building archaeology methods, closely connected to archaeology. His most important activity was his research on Prague Castle.

[6] A compendium about the monastery with rich documentation from the war time: Soukupová 1989.

[7] Reichertová 1955, pp. 174-183.

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[10] Chotěbor 1987.

[11] Radová 1972.

[12] Škabrada 1996, pp. 105-118.

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[16] Completely published in German: Hauserová/Rykl 2011.

[17] Durdík 2007, p. 9.

[18] Gersdorfová 2010.

[19] Selected literature: Mayer 1971; Benešovská 1998; Benešovská 1996; Škabrada/Rykl 1996, pp. 12-16.

[20] After the analysis of the basic building structure in the basement, even after later changes, it seems like no older building fabric had been used, except in the eastern wall, which belonged to the residential wing, on which the eastern wall of the tower was built.

[21] Compared to old interpretations, which had assumed there had been a hall. About the triple alcove as a significant aspect that could be interpreted as ceiling of the room, see also: Škabrada/Rykl 1996, pp. 12-16.

[22] Some examples from German literature: Strobel 1976, pp. 144, 145, 197, 198; Phleps 1967, p. 239; Nay 1998; Schröttel/Haußmann 1994; Beispielhafte dreifach gewölbte Holzstube um 1400: die Burg Trostburg in Südtirol, Institut für Mittelalterliche Realienkunde – digital image collection, http://tethys.imareal.sbg.ac.at/realonline/ Trostburg, 25.6.2013.

[23] Exhibition in Autumn 2010 on the occasion of the 700th anniversary of the royal wedding of John of Luxembourg with the last member of the Přemyslid dynasty, Eliška (Elisabeth). Editor of the exhibition: Klára Benešovská. The exhibition was held in the house Zur Glocke. Virtual tour by Vojtěch Dvořák.

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3D Reconstruction of Cultural Heritage Artifacts

A Literature Based Survey of Recent Projects and Workflows

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3D modeling technologies have gained importance as tools for the reconstruction and visualization of Cultural Heritage artifacts during the last decade. But there is still only little systematic research about how and for which purposes these technologies are used. Further on from a methodological perspective, it would be necessary to understand how 3D modeling is affected by disciplinary boundaries and challenges specific to historic topics. For the investigation of these topics, the authors have completed a content analysis of 478 conference papers and articles related to 3D reconstruction modeling in the field of humanities. The main objective was to identify current topics, technologies and institutions involved. Most of the projects described in those publications dealt with data acquisition and model building for existing artifacts. Only a small number of projects focused on structures that no longer existed physically. What are the current trends regarding 3D reconstruction of Cultural Heritage artifacts? On the one hand, there are many individual projects using 3D technologies to reconstruct historic items. Research shows that such reconstructions are most commonly used for presentation, research purposes and sometimes for digital conservation of large buildings or city models and often realized by interdisciplinary workgroups. In the implementation process a wide scope of technologies is used and new technological developments are quickly adopted as well as current socio-technological trends like crowdsourcing or mobile computing. On the other hand these projects are mostly prototypic and an implementation as everyday technologies is still in progress. There are many efforts to handle this challenge. Nowadays, large scale funding schemes, international networks and research facilities support the development of cost efficient tools, workflows and standards. Beside these findings, the authors identified a vivid scientific community and their protagonists. Since 3D is becoming a common and easily accessible tool for historical reconstructions, issues such as quality standards, compatibility, sustainability and requirements of focus groups are increasingly prominent in academic discourse, but were implemented in only a few practical projects so far.

3D Reconstruction and Cultural Heritage

When determining Cultural Heritage as a sum of remaining items traded from former times, 3D modeling technologies offer a chance not only to digitize historic artifacts which are still extant but to reconstruct even objects virtually, which are no longer extant physically but only known from descriptions. Until the year 2000 3D visualization of cultural heritage artifacts was used merely as digital replacement for physical models.[1] It is only since the new millennium that a wider usage has occurred. Nowadays 3D models are mainly used to visualize historic items to the public as well as for research purposes and for education.[2] Beside that there are many other purposes for 3D technologies like Cultural Heritage Management and conservation tasks, research or even advertising. In most of the cases researched 3D models had not been created for one of these purposes alone but also for focusing on various objectives. Workflows for a virtual reconstruction of extant artifacts are mostly technologically or logistically challenging, but a virtual reconstruction of no longer extant objects adds tasks like an interpretation and inclusion of describing historic sources. While especially for these interpretation tasks archaeologists and art historians are involved, there are – as we will analyze closer due this investigation – many scientific disciplines dealing with a 3D reconstruction of cultural heritage content.

Methods

There have been many investigations to determine the use of 3D for Cultural Heritage as a field of research during the last years.[3] One of the latest and most elaborate examples was the EU project EPOCH, which finished in the year 2008.[4] The project involved many leading European institutions and protagonists analyzing a current state as well as future perspectives and challenges. Another long term research project is VIA, which is surveying and supervising the workforce and cooperation in the field of archaeological illustration in Britain.[5]

Research Objectives

While most of these investigations focus on certain aspects, there has been little systematic research especially for 3D reconstruction based on empirical findings until now. Our main objective was to sketch a current state based on an empirical analysis of recent publications. What are our research questions? On the one hand our research interest deals with the current usage of that technology. This includes the question for current use cases, workflows, collaboration and standards. On the other hand the question was for a scientific community and its discourses. Topics inherent are institutions, protagonists and current academic discourses.

Analysis

To cope with these challenges we performed two stages of analysis: the first stage was a content analysis for publications to examine current usage scenarios, protagonists, field of research.[6] To enable a selection of relevant publications experts were asked to examine the most valuable conferences and publications. As scope for conference proceedings whole volumes were included, and an identification of relevant journal articles took place via keyword search. All publications included had to be written in English and be made available online. In our analysis a sample of 452 journal articles and conference proceedings were included during this first stage. Most of the projects described in those publications dealt with data acquisition and model building for existing structures. Only a small number of projects focused on no longer extant architecture. That kind of project in particular seems to be interesting for a study of the linkage between digital technologies and traditional humanities. To examine this linkage the authors applied a qualitative Grounded Theory analysis with a sample of another 26 international publications dealing with a reconstruction of no longer extant objects.[7]

Publication	Volume
3DArch Conf.	2005-2009
CAA Conf.	2007, 2009
VAST Conf.	2003-2007, 2010
Imaging Ancient Rome Conf.	2006
Virtual Palaces Conf.	2012
Journal of Cultural Heritage	2000-2011
Various project reports dealing with no more extant objects	1999-2011

Table 1 – Sample.

How valid are results from such an empirical analysis? Focusing on potential lacks, beside sources of error depending on data mining and empirical evaluation methods, publications generally more often than not represent academic activities and less a situation of commercial institutions.

Findings

Authors and Cooperation

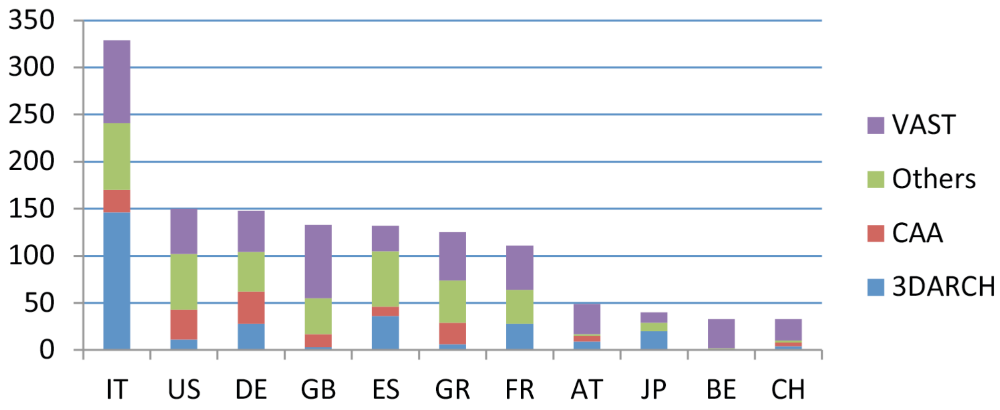

Fig. 1 Nationality of authors.

Data for an identification of an author's nationality was taken from the correspondence addresses noted in the publications. The most named nation is Italy with a percentage between 15% and 60%. Altogether authors in this sample are affiliated to 38 nations, a high quota is located in Europe. With regard to their respective disciplines, most authors are affiliated to institutions dealing with computing. This quota widely spreads between single conferences, i.e. roundabout 70% of VAST presenters are affiliated to computing institutions.[9]

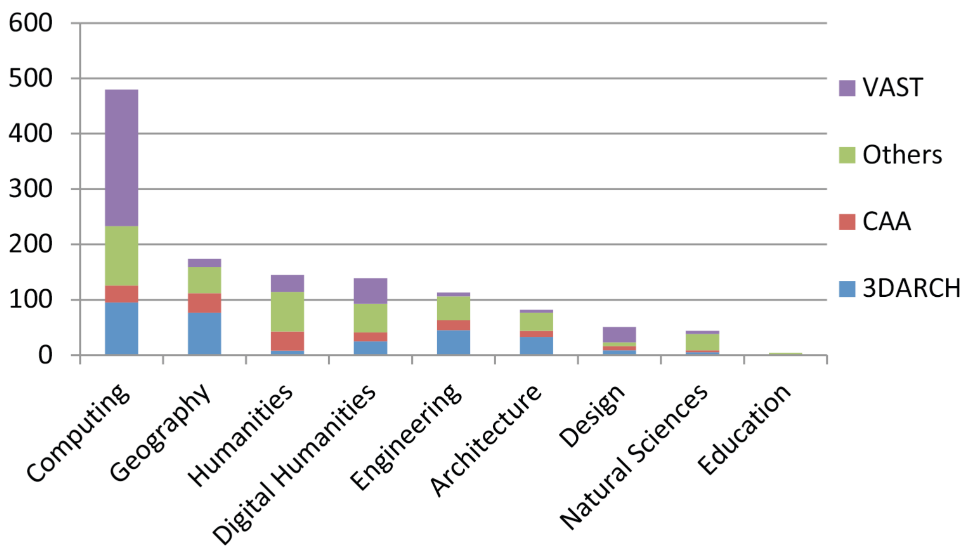

Fig. 2 Disciplinary affiliation.

Another hypothesis was that collaborative publications would inherit a knowledge communication between authors. Depending on sociological role theory, there are certain members in social communities who play an important role for sharing and broadcasting information especially across disciplinary and national borders.[10] To identify these protagonists or *multipliers* and a scientific network we performed a social network analysis.[11] Nevertheless, such information transfer is just assumed and there are no possibilities to reconstruct intensity or even an existence of information transfer between authors from data.

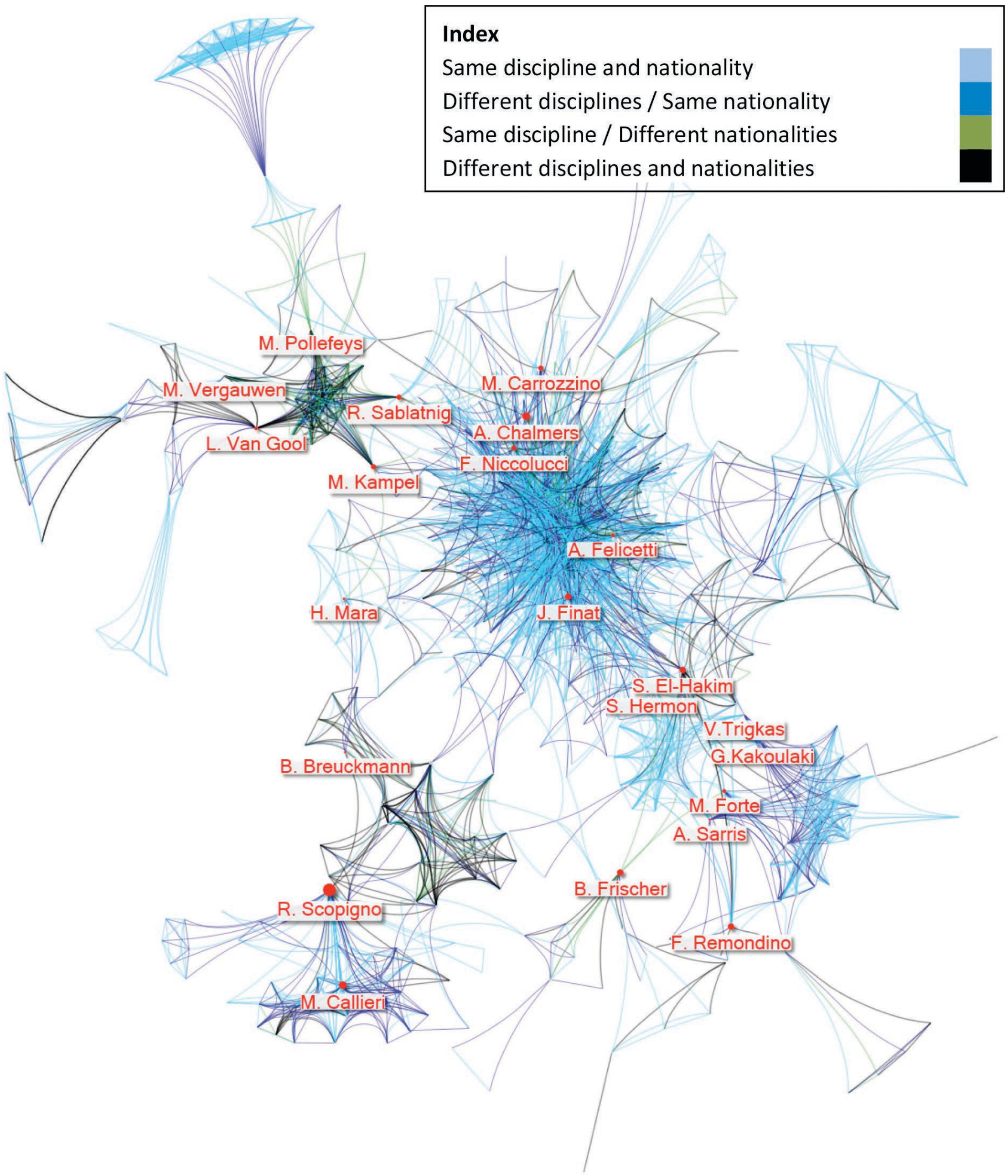

Fig. 3 Author-co-author relations (multipliers highlighted).

Publications have been written by 1500 persons and containing over 3000 links between authors of cooperative articles. Most of the publications have been written by authors belonging to the same discipline and nationality. But there are also several international or interdisciplinary networks visible whose members have written more than just one common publication. Also some important multipliers could be identified, which connect groups of researchers to each other. To validate, results were discussed with experts, too. Generally these multipliers identified are not only active publishers but often key role players in community in other ways, too, i.e. as members of scientific committees, as conference chairs or as initiators or leaders of projects.

Topics and Methods

Another research interest was to identify current conference interests and content of contributions. To examine this we included a sample of 339 articles in conference proceedings.[12]

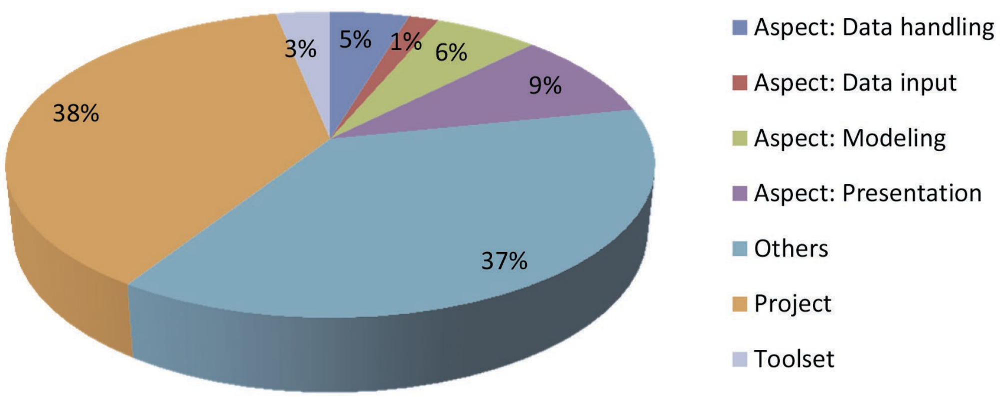

Fig. 4 Proceeding themes (n=339).

Over one third of conference contributions (37%) neither deal with 3D modeling nor historical objects. Nearly the same quantity of articles are reports about single reconstruction projects. This means that they describe workflows to reconstruct certain historic items as 3D models. Another group of contributions deal with certain aspects of 3D reconstruction for historic purposes like presentation and modeling strategies, data acquisition methods or a handling and classification of 3D data. Focusing only on project reports, there are two main strategies for reconstruction, depending on whether the object to be reconstructed is still extant.[13] In case of still extant objects a digitization mostly takes place via data acquisition and algorithmic model building. For acquisition various technologies are used, depending on the type and proportions of the item, i.e. photogrammetry, laser scanning, LiDAR (light detection and ranging) or for specific purposes even magneto resonance acquisition or even computer tomography.[14] More than 2/3 of project reports deal with such a combination of data acquisition technologies and automated model reconstruction for extant objects or its fragments.

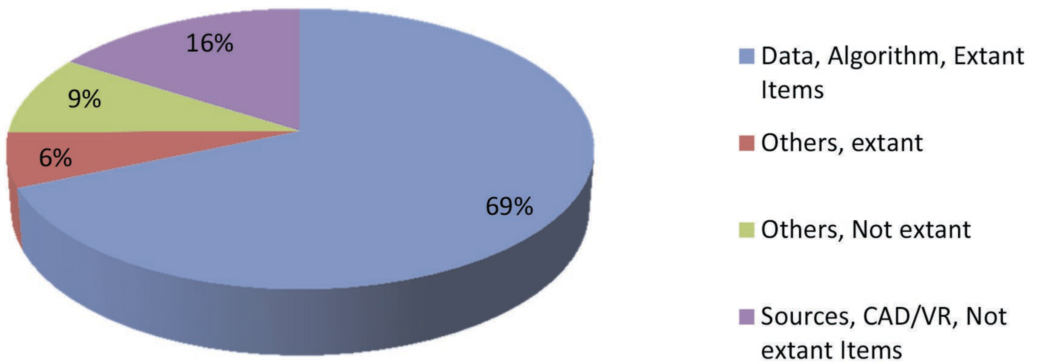

Fig. 5 Project reports (n=175).

A proportion of 16% deal with a reconstruction of no longer extant objects from historical sources. In these cases a model creation takes place via VR or CAD modeling.[15] Technical workflows for the creation of these models have been similar for more than a decade,[16] but output quality and tools have changed rapidly. Most of these projects are realized by interdisciplinary teams using standardized 3D software for model building. While output qualities and inherit sources are widely depicted in publications, the research of interdisciplinary cooperation during these projects is still lacking. Beside these main types there are several projects where, for example, data driven automated reconstruction is used to reconstruct no longer extant objects. Objects reconstructed by these projects are often architectural structures or arts, mostly religious buildings like churches or temples. Most items are located or originated in Italy, Spain or Greece. With regard to the time of origin of these objects, most projects deal with content from the Roman, late medieval or modern times.[17]

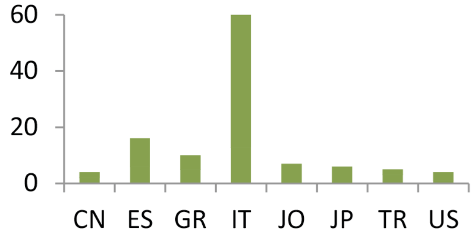

Fig. 6 Location of artifacts (top 8).

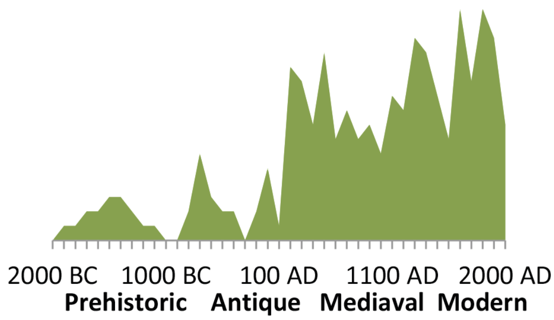

Fig. 7 Time of origin of artifacts.

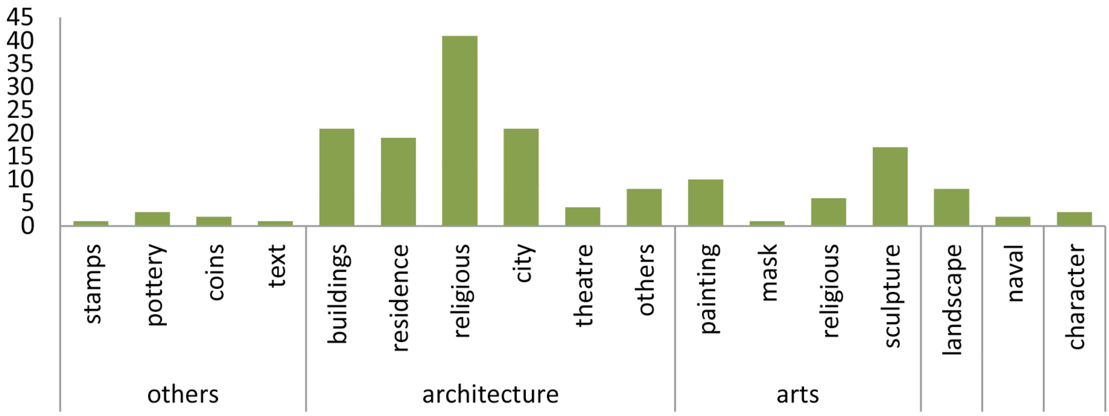

Fig. 8 Types of artifacts.

Workflows

While a reconstruction of still extant objects is challenging for mainly technical aspects like complete and accurate data acquisition and handling or an efficient and comprehensive algorithmic model creation, technical workflows for a VR or CAD modeling of no longer extant objects are widely established and similar to other 3D modeling tasks like engineering and design. Specific challenges for such interpretative reconstructions are more a case of coping with historic sources or interdisciplinary workflows.

Input[18]			
Historical sources	Historical pictorial sources	*i.e. ground plans, panorama*
	Additional historical sources	*i.e. documents, eye-witnesses, coins*
Contemporary sources	Contemporary pictorial sources	*i.e. plans, photography*
	Data sources	*i.e. laser scan, photogrammetry, GIS*
	Additional contemporary sources	*Findings, research output*
Logical implication	Architectural systems	
	Analogies	*As "Comparison to similar objects"*
	Inner model logic	
Modeling		
Automated	Algorithmic modeling	
Semi- automated	Rule based modeling	*i.e. Procedural generators, Construction kits*
Manual	CAD/VR modeling	
Output		
Static		*i.e. Illustration*
Dynamic		*i.e. Animation, Audio visual Presentation*
Interactive		*i.e. Augmented Reality, Web Application, Games*
Physical		*i.e. Rapid molding*
Data		*i.e. FEM-Analysis*

Table 2 – 3D reconstruction process – taxonomy.

Especially the quality of sources highly influences the validity of resultant models: especially for no longer extant objects historical sources or contemporary remnants seldom deliver all information required for a reconstruction. To attain a coherent model many decisions are based on logical implications like analogies to similar objects, requirements of an architectural system such as the Vitruvian system, or simply on inner-model logic as with common boundaries of modeled parts.

Acquired data, which is mostly available for extant objects only, gives the opportunity to build models in a highly automatized way via algorithms. For such modeling methods there is currently a lot of research and development to reach fast, reliable and flexible algorithms. But also for the modeling of no longer extant objects, which is mostly done in traditional CAD/VR matter, there is some effort to automatize certain process aspects. An automated form of processing of logical implications is focused on in some projects going as far as libraries of pre-constructed parts used in some construction kits.

Another closely related issue is quality management during the modeling process.[19] One important strategy is to set up guidelines for workflows which are related to process or model quality. Depending on the type of input data, model related guidelines define a level of accuracy to be achieved or criteria for a selection of objects to be reconstructed and a level of detail necessary. Process related guidelines define rules for workflow, i.e. for transparency, to conform to 'Good Scientific Practice'. Closely related to that are strategies for quality assurance. There are two main strategies described in papers, on the one hand external committees like boards of experts, on the other hand internal editorships involving a board of team members and ensuring quality via audits.

As figured out in the beginning of this article, there are many different purposes for such 3D models which highly influence type and quality of output. Most important are depictions of these virtual models, either as static pictures, such as illustrations or in a dynamic form like animation and increasingly their use in interactive applications, too. One important issue is that such output is mostly visual oriented but some projects also focus on multi-sensual outcome from such 3D models, including, for example, aural impressions. In other cases a 3D model would be used as data input for other analytic steps, for example to perform FEM (Finite element method) analysis or hydraulic simulations, or to create physical prototypes.[20]

Implications

What are the current trends and discourses to be found in current publications concerning the use of 3D technologies for digital heritage?

On the Way from Prototypic to Daily Use…

Hitherto most 3D reconstruction projects have been prototypes and an implementation as everyday technologies is still in progress. There are many efforts to handle this challenge. During the last years large-scale funding schemes, like the EU ICT grants, support the development of cost efficient tools, workflows and standards.[21] Also at conferences many contributions report about such cost efficient and easy to use strategies. But nevertheless, currently most of the tools developed or workflows presented often either offer highly automated workflows for very special use cases, or still need IT-skilled operators and manual operations.

Fast Adoption of New Technologies

There have been many technological developments during the past few years for 3D modeling and visualization. Generally these inventions are speedily adopted for cultural heritage purposes, too. In publications there is a huge range of technologies described which are used or sometimes 'abused' for such purposes, i.e. medical computer tomography[22] for data acquisition or CAVE-like environments for visualization. Also modern technological trends like Smartphone or Web 2.0 are quickly adopted as well as current socio-technological trends like crowdsourcing[23] or mobile computing.

Standardization, Sustainability, Sharing?

While such adoption of modern technologies and trends mostly occurring in a prototypic way, aspects for standardization of quality, compatibility, sustainability and requirements of focus groups are increasingly prominent in academic discourse, too. For a creation of 3D models there have been many prototypic workflows, guidelines and strategies developed as well as conventions for presentation and visualization.[24] Nevertheless, these guidelines are implemented for single projects only, especially regarding the reconstruction of no longer extant objects.[25] A similarly situated aspect is a documentation of the models created. While Metadata as a standard for documentation seems widely accepted in academic discourse, there are many different classification schemes fostered by their inventors and no unified standard seems in sight.[26] While the documentation of the project outcome is often discussed, the documentation of the creation process itself is very seldom thematized.[27]

Institutions: Digital Humanities and Knowledge Networks

As figured out there are many players like international networks and research facilities dealing with 3D Cultural Heritage content. In publications researched, academic institutions like universities or research facilities with various disciplinary backgrounds are often named. Beside that there are an increasing number of institutions or networks specialized in 3D Cultural Heritage topics, i.e. Digital Humanities research facilities or commercial institutions. But at the moment these are still less prominent in publications.

Beside these institutions a considerable amount of cooperation networks have been funded during the last years. This means disciplinary societies like *Computer Applications & Quantitative Methods in Archaeology (CAA)*, societies and infrastructures dedicated to certain aspects of education, standardization or coordination like *Europeana, DARIAH* or *PALATIUM* as well as communities of practice like the British *Computer Vision Groups*.[28]

Presentation and Publication

Another topic which is prominent in academic discourse is the question of presentation. Actual discourses favor a user friendly presentation look, with a main discourse about photorealistic presentation vs. non photorealism. Another trend is to move on from a presentation of static artifacts to complex and lively impressions of history, involving enhancement of visualization with dynamic elements like crowded places.[29] Other trends are concerned with a presentation of content. This includes an increasing use of interactive Web presentation environments like Google Earth,[30] as well as a materialization of virtual 3D models via rapid prototyping methods or multi sensual presentation possibilities.[31]

Summary

Are research questions answered? At a glance 3D technologies are widely established and used in many reconstruction projects for Digital Heritage artifacts. Especially statues and buildings in Mediterranean countries dating from all periods AD deliver rich content for such reconstruction. Also there is an evident scientific community involving researchers from various disciplines and many countries, whereby computing as a discipline and Italy as a country are most prominent.

While new technologies and trends are quickly adopted, an implementation as every-day technology for cultural heritage purposes is still in progress. Fields of this work are a development of cost effective and easy to use tools and workflows as well as a definition of common standards or an enhancement of cooperation and education. While these topics are prominent in academic discourse and funding objectives, a wide implementation in practical projects is still outstanding. Irrespective of the wide scope of research for 3D technologies there are still several outstanding topics like an investigation of interdisciplinary cooperation workflows, a scientific reconstruction of complex, dynamic systems or proven educational concepts for the training of historians or archaeologists in the use of 3D technologies.

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Illustrations

Table 1-2 and fig. 1-8 Authors.

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[3] Frischer 2008.

[4] Arnold and Geser 2008.

[5] Gibbons 2012.

[6] A short version of this paper will be published in: Münster and Köhler in print. For methods see: Mayring 2000.

[7] Münster 2011.

[8] Selection of important articles took place via Keyword based search.

[9] For 21% of authors the respective disciplines at affiliated institutes could not be identified or not distinguished precisely.

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[12] Because a search of relevant journal articles took place via keyword based search, these articles had been left out.

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[17] Many projects do not reconstruct objects from one certain age only but various time slides or an evolvement over time. For projects which deal with content from different centuries each century affected was counted.

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[31] Erving, Rönnholm and Nuikka 2009.

Visualisation of Uncertainty in Archaeological Reconstructions

(Transcript of Lecture)

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The Visualisation of Uncertainty is a method to explicitly demonstrate the hypothetic character of archaeological reconstructions. It combines sketches with abstract models and assumes that both, perception and meaning, will be adopted. By this, the Visualisation of Uncertainty, too, would be read intuitively. Both, sketches and abstract models, have in common their share of the undefined. The degree of the undefined is variable and adjustable. Furthermore, the lack of definition does not have to be a lack of information. On the contrary, the lack as such can carry the most important information: the need for further decisions or the existence of a multitude of possible completions.

The project started as an individual experiment initiating a cooperation with the chair for building history. On the basis of the first results we joined the Sculpture Network Berlin and became financed by the Excellence Cluster TOPOI 'The Formation and Transformation of Space and Knowledge in Ancient Civilizations', financed itself by the German Research Foundation DFG in order to project the whole city of Pergamon. The network provides us with knowledge and information about the current hypotheses. The German Archaeological Institute's office in Istanbul, official excavator in Pergamon, is working with us in close relationship particularly in city layout and in modeling detailed architectural parts.

We will attempt to explain our approach with a recourse to the basis of visual architectural representations: sketches are suggestions. While the depictive sketch works out the essences, the design sketch materializes a thought. If sketches look unsharp, the ideas that they represent are also unsharp, and therefore uncertain. In design sketches this uncertainty is intended, so sketching in the design processes is actually visualizing uncertainty. And this uncertainty is the link between architectural design and archaeological research. While the designer may leave decisions to be made in a later state, the archaeologist's knowledge may be incomplete or ambiguous. In short form: design does not want yet, archaeology does not know yet (to determine further details).

Fig. 1 Pergamon 200 AD, temple of Zeus. (Virtual photography of digital 3D model, 2011).

In archaeology, reconstructions reflect the state of research (fig. 1). In some cases though, the information is not sufficient at all for a reconstruction. It depends on the state of the ruins, if you can reliably reconstruct in three dimensions. In some cases it is only sufficient for an outline. A complete antic city's appearance can therefore only be partly based on scientific research. In this case, a reconstruction is based on analogies or hypotheses. The aim of the Visualisation of Uncertainty is to establish methods of representing uncertainty and its degrees – and to visually emphasize the existence of uncertainty.

In the field of archaeology two dimensional methods for representing uncertainty have already been established. Perspectives look from selected points of view or hide those areas that are uncertain. Physical, haptic models on the other hand cannot fulfill this demand, since you can freely look around. By contrast virtual computer models can. But the idea of a model has to be considered different from a physical model. In general, a model is a theoretical construction, far more than bare geometry. A model may contain a multitude of geometries, several states, links, constraints or any other kind of information. This means that the representation of the model changes and varies in any aspect. The main focus within the Visualisation of Uncertainty is this differentiation.

Obviously visualized uncertainty will rarely look realistic. The reason for this is that most hypotheses leave many things undefined. If the hypothesis is extremely vague there is little to be represented. But more precise information by the archaeologists may not be available. So there must be something in between. A certain formal and visual constraint to get convincing images, that show the hypothesis itself as well as its degree of uncertainty. This lead us to a set of methods:

Geometric Simplification turned out to be the most intuitive way to represent uncertainty. In circumstances other than archaeology this might be misinterpreted as contemporary design (fig. 2). Geometric contrasts furthermore clearly show the different degrees of certainty. Again, it is the context of archaeology that excludes an interpretation as a design sketch (fig. 3).

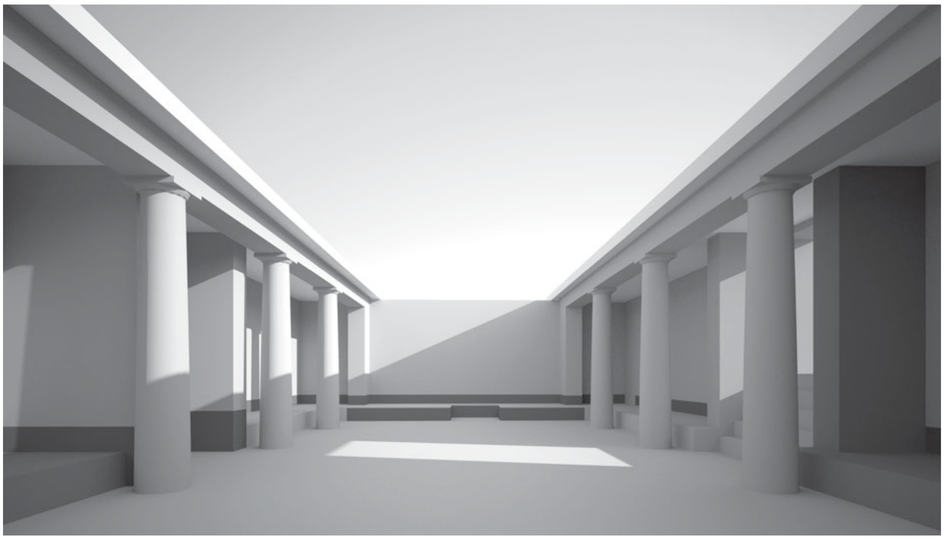

Fig. 2 Pergamon 200 AD, temple of Hestia. (Virtual photography of digital 3D model, 2008).

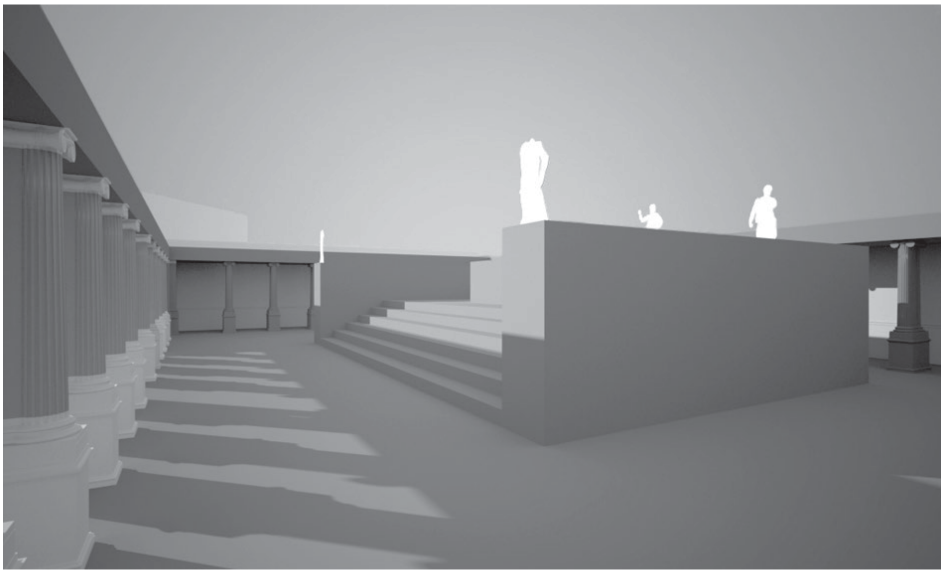

Fig. 3 Pergamon 200 AD, court of Great Altar. (Virtual photography of digital 3D model, 2008).

Transparency only pretends to convince. Indeed, transparency is disturbing, since it suppresses and distorts the natural spatial impression. Transparent objects neither represent a spatial situation with nor without them. Instead of visualizing two options, transparency visualizes none of them, but informs about this uncertainty in a non-spatial, rather theoretic way. The spatial representation therefore does not focus on spatial perception, but on abstract information, just as the verbal hypothesis does. This is why we apply transparency only in axonometries that match the diagrammatic meaning of transparency (fig. 4).

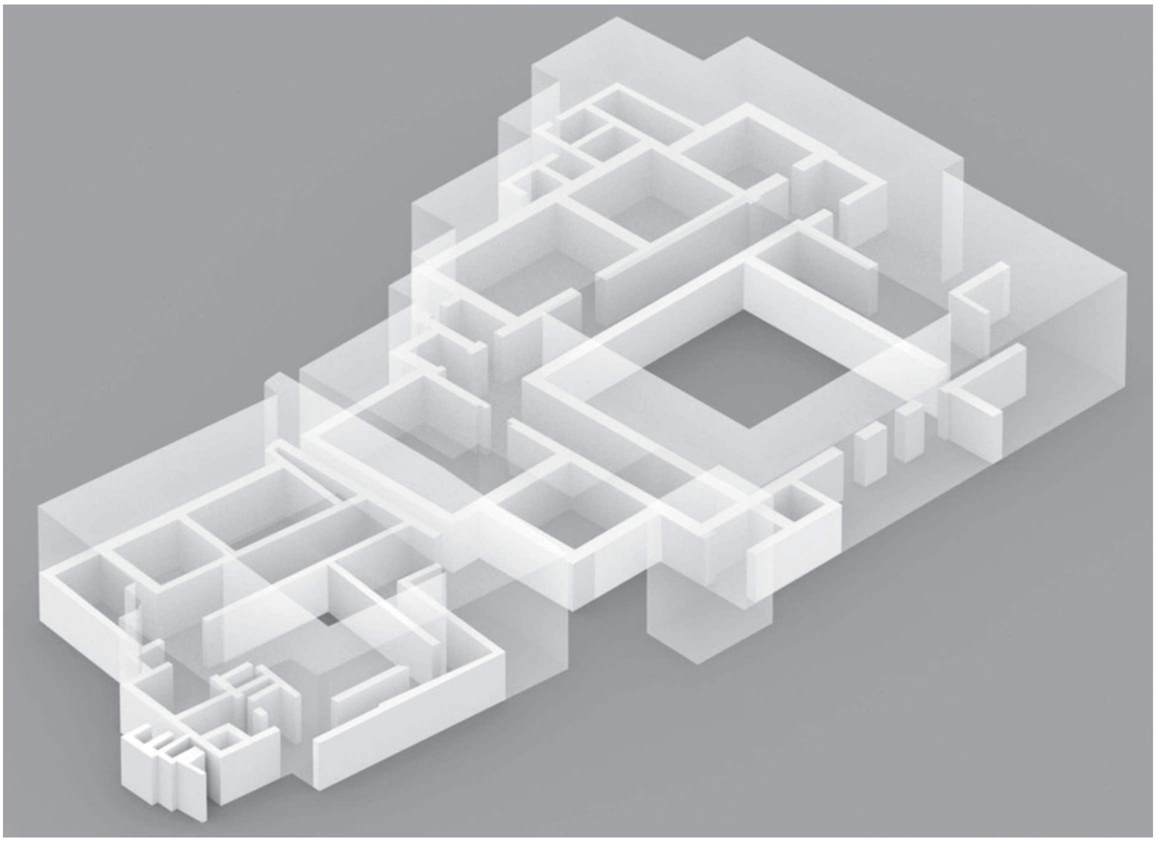

Fig. 4 Pergamon 200 AD, palaces IV and V. (Virtual photography of digital 3D model, 2008).

Lines in space instead do not suppress the natural spatial impression. They indicate that beyond the shown spatial impression there is supplemental information. In this example, the smaller temple relies on certain reconstructions. The wires show an outline of a larger temple that might have originally been planned at this site. Some building parts used in the small temple would certainly match the larger one. The hypothesis is therefore that after some parts had already been finished, the overall size was reduced, probably because the slope of the site is too steep (fig. 5).

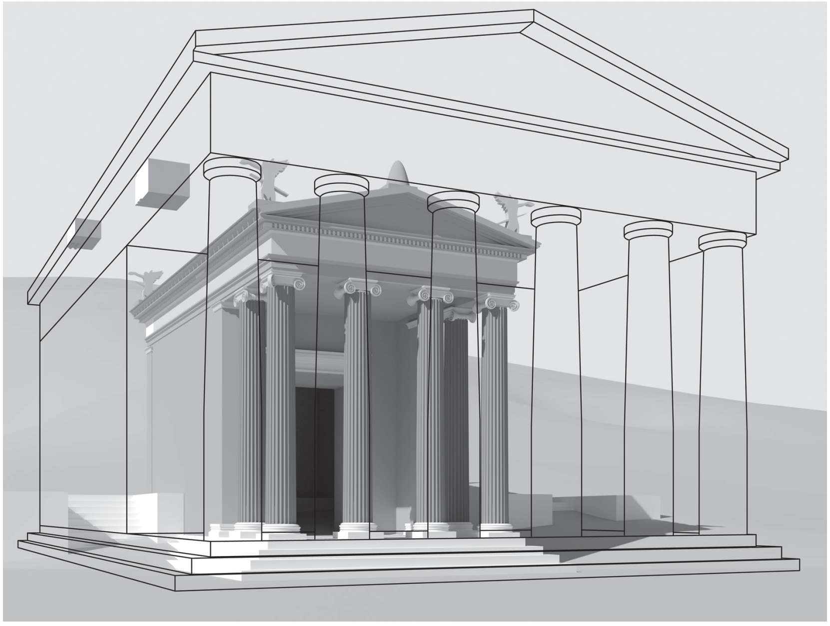

Fig. 5 Pergamon 200 AD, temple R. (Virtual photography of digital 3D model, 2008).

If there are contradictory hypotheses, it seems impossible to maintain the spatial qualities and the ambiguity at the same time. In this case, we show the hypotheses separately, so it is clear, that all hypotheses are equally significant (fig. 6).

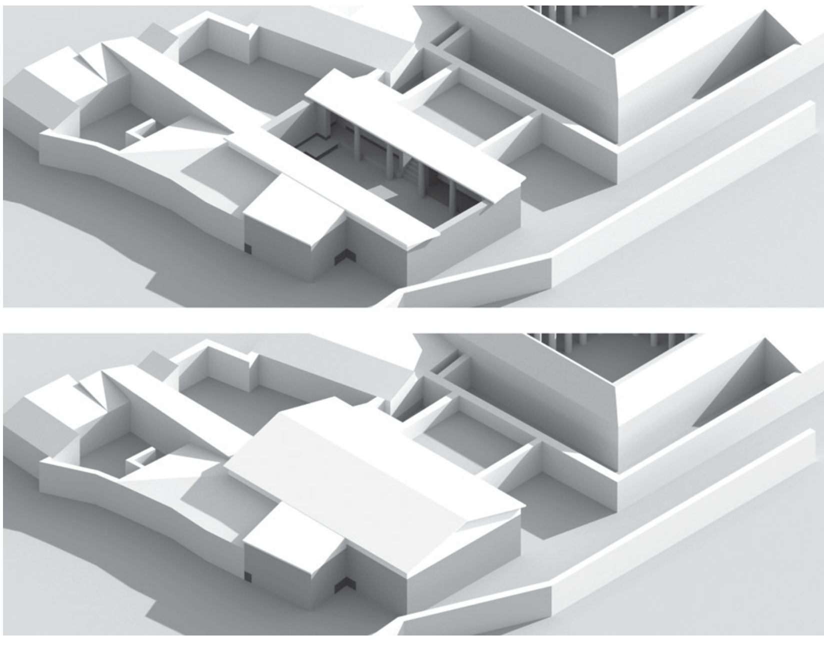

Fig. 6 Pergamon 200 AD, temple of Hestia. (Virtual photography of digital 3D model, 2008).

Levels of detail have to be reconsidered as well. In Visualisation of Uncertainty, their purpose is as follows: Too many details contradict the uncertainty, while too few details obscure the spatial character. Flat roofs for instance suggest a completely different cultural environment than pitched roofs. On the other hand, it seems that windows do not have an effect on the identification of buildings (fig. 7).

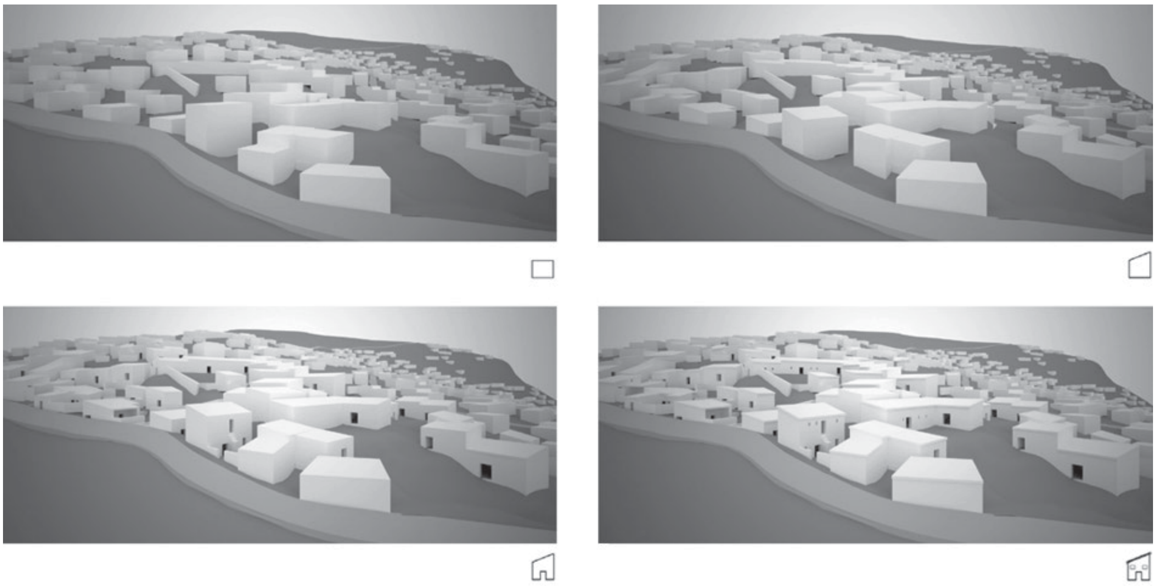

Fig. 7 Pergamon 200 AD, byzantine housing. (Virtual photography of digital 3D model, 2008).

In order to make the visualized uncertainty as self-explanatory as possible we defined a set of conventions: First of all the visualization has to maximize the spatial impression. This means that whatever method is appropriate to represent a building's or situation's uncertainty, the natural spatial impression has to be considered very carefully. In other words, if a method would distort the spatial impression, it should not be used. Three main aspects are responsible for an appropriate spatial impression: the projection and the view point, the unambiguous presence of solids and the lighting.

Just like in architectural photography, the natural perception depends on the perspective projection. First, a perspective is either viewed from a bird's eye or from eye level. Second, the projection plane is either perfectly vertical or undoubtedly tilt. And most important, there is nothing in between (figs. 8-9). Even more explicit than bird's eye perspectives are parallel projections, and even more clearly diagrammatic are tilt axonometries like ground plan axonometries (fig. 10).

Fig. 8 Pergamon 200 AD, Traianeum. (Virtual photography of digital 3D model, 2011).

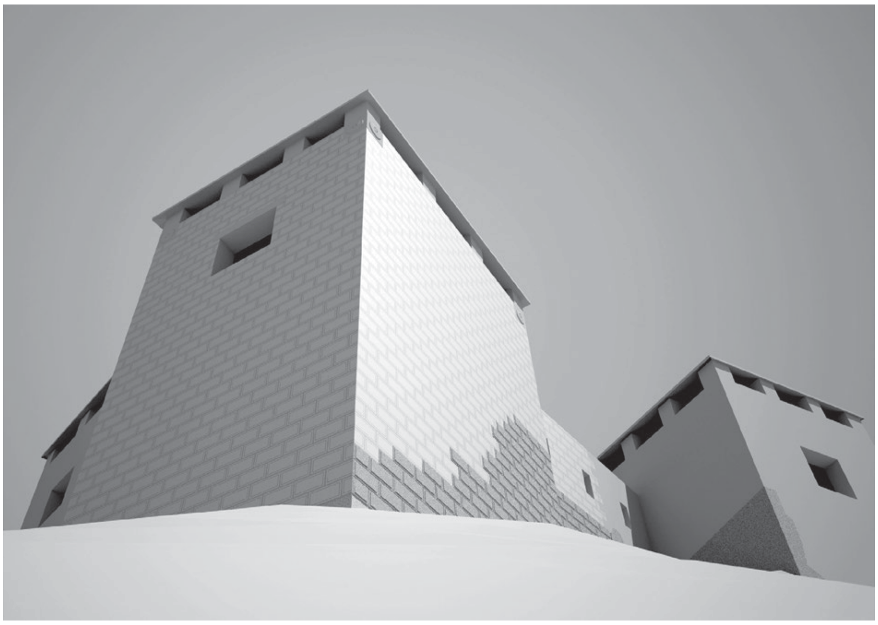

Fig. 9 Karasis, fortress, ca 2nd century BC. (Virtual photography of digital 3D model, 2009).

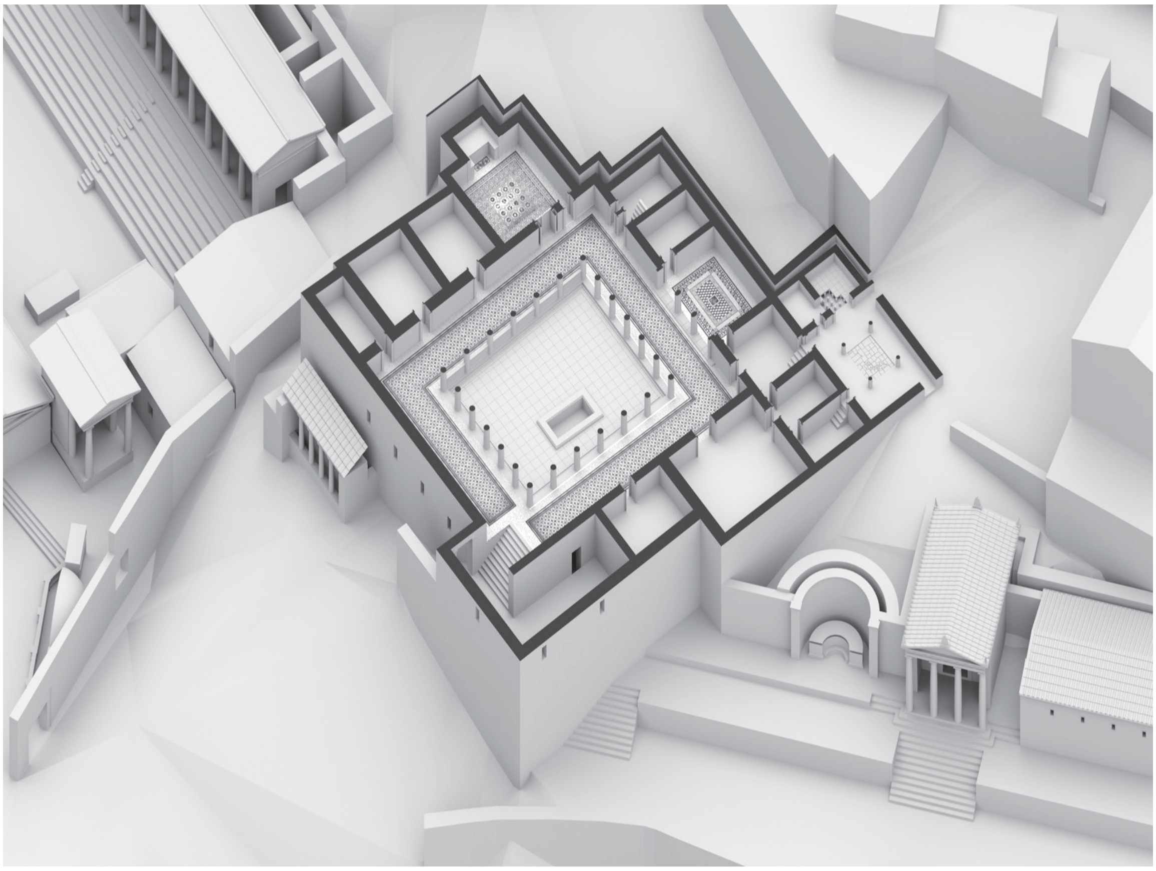

Fig. 10 Pergamon 200 AD, building Z. (Virtual photography of digital 3D model, 2011).

The undoubted presence of solids ensure that if volume is part of the visualization, it will also be perceived as such. Transparencies contradict this and hinder the understanding of a spatial situation. Either there is an object, and in this case its rear is invisible, or there is not an object and the view is not obscured. With transparency, the spatial impression is distorted (fig. 11).

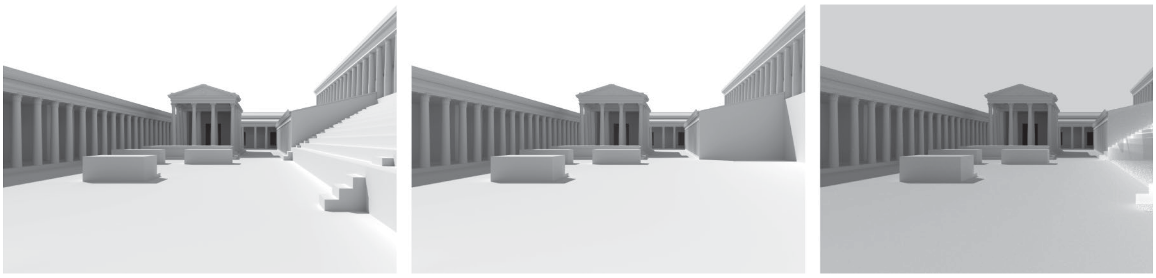

Fig. 11 Pergamon 200 AD, sanctuary of Demeter. (Virtual photography of digital 3D model, 2010).

Finally the spatial impression depends on the lighting. The lighting should not contradict the information about uncertainty. If a scale of shading is used to express the degrees of uncertainty, the lighting must be set to undoubtedly leave the scale untouched. The degree of uncertainty can range from observable remains to absent parts and objects whose former existence is absolutely certain to assumptions firmly rooted in science. So light must not interfere with this code (fig. 12).

Fig. 12 Pergamon 200 AD, gymnasion. (Virtual photography of digital 3D model, 2011).

The second convention ensures the unity of the visualisation, or in other words, the compatibility of the single parts of a visualisation. A convincing impression of a large city can only be achieved if the buildings suit one another and form a unity. This is far more important than the individual uncertainty. Otherwise, if some buildings were detailed while others were rough sketches, the overall impression would be unsuitable (fig. 13). We are working on the balance between the highest detail possible and the least detail necessary, to achieve a look that is adequate and homogeneous at the same time. For large city overviews we introduced a cubic grid of one by one by one meters: objects that fill more than half of this one meter cube are shown, while objects that do not fill half of the cube are not shown. This does not work down-the-line, so there are exceptions to the rule. Columns for example clearly fill less than half of the space. But if you consequently left them away, colonnades would simply disappear. It is the same with steps and sculptures (fig. 14).

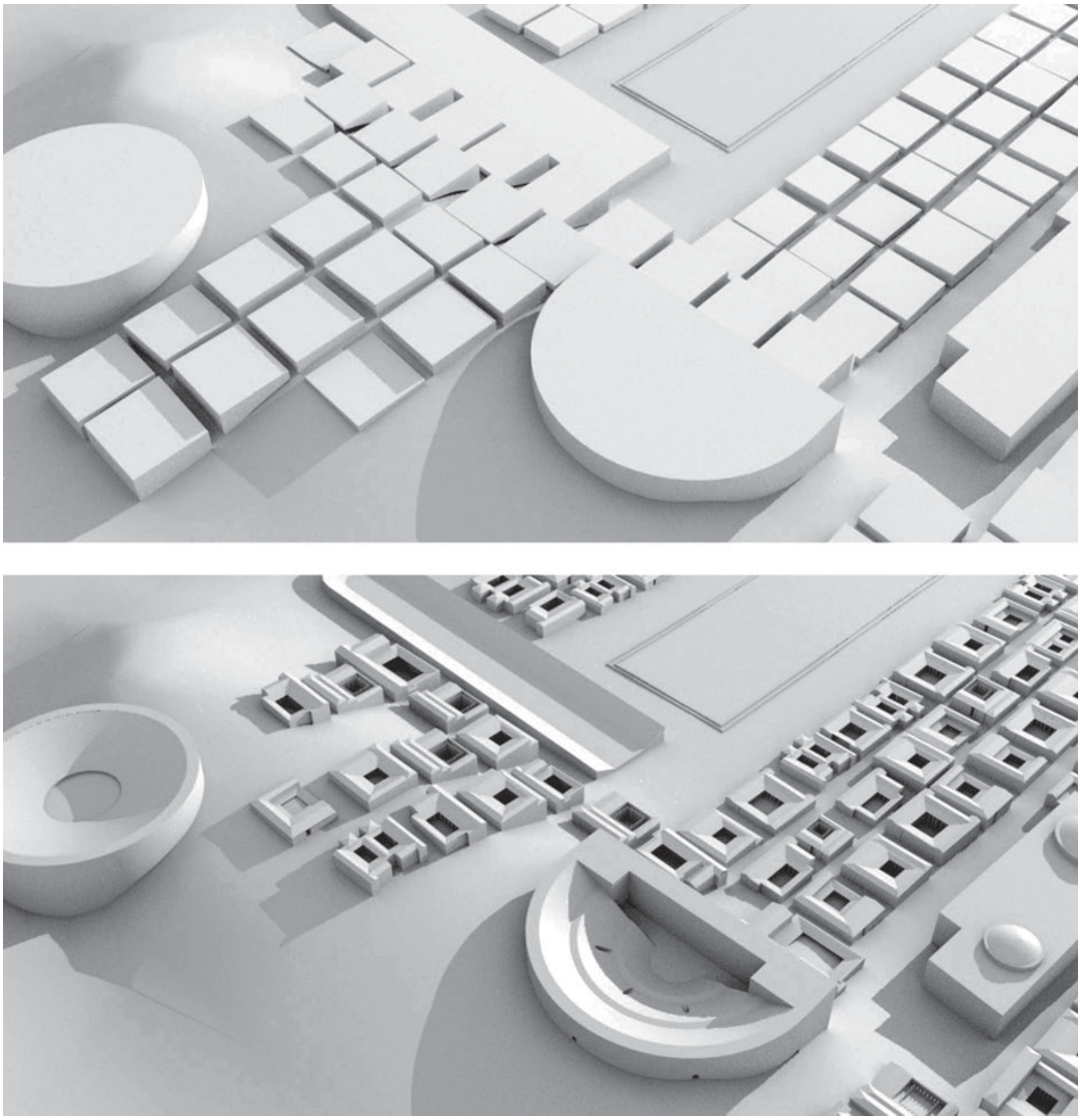

Fig. 13 Pergamon 200 AD, roman city extension. (Virtual photography of digital 3D model, 2008).

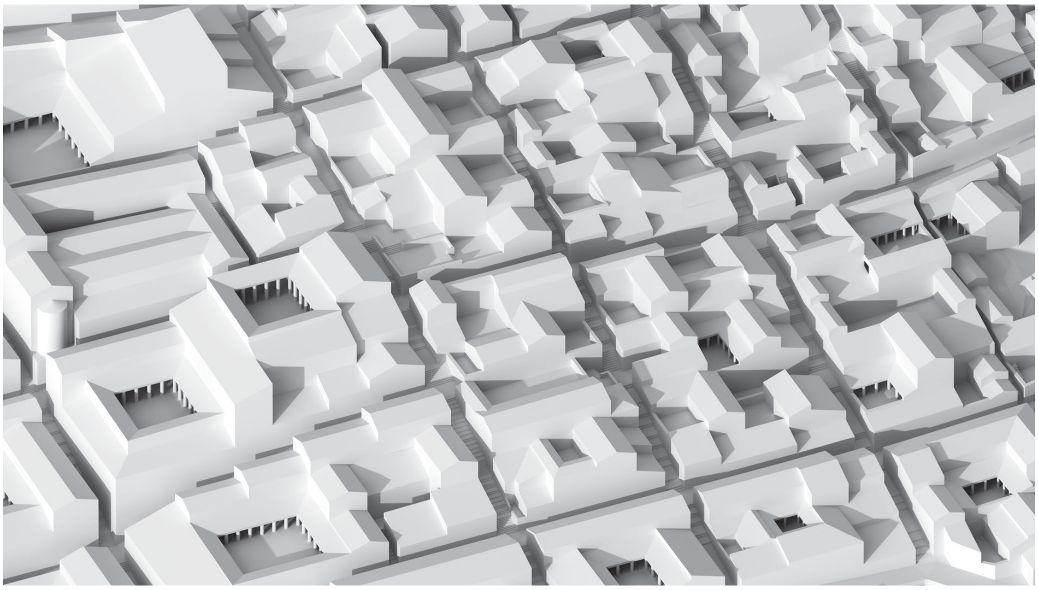

Fig. 14 Pergamon 200 AD, eastern hillside. (Virtual photography of digital 3D model, 2011).

In the case of the visualisation of Pergamon we altered this convention and maximized every individual building's detail according to its individual degree of certainty. This has been agreed in order to visualize the archaeological state of research. This is why there is detailed architecture next to abstract geometry. Still this mainly matches the state of knowledge, so this decision does not contradict the visualisation of uncertainty (fig. 15).

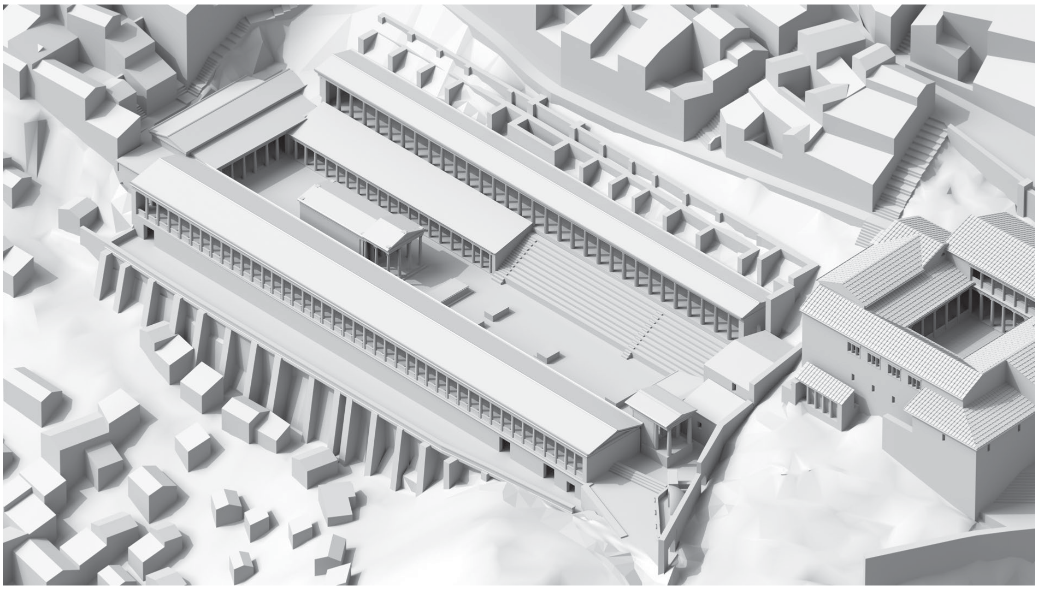

Fig. 15 Pergamon 200 AD, sanctuary of Demeter. (Virtual photography of digital 3D model, 2012).

The third convention concerns the flexibility of the virtual model. The purpose is to associate the viewer's distance with the individuality of the method of representing uncertainty. This means that the closer one gets to a single building, the more individual its uncertainty can look. And the farther one gets, the more the look becomes homogeneous. This dynamic change again excludes the use of physical models.

Here also the visualisation of Pergamon focused on an overall geometric state of research to function as a reference for further research. Apart from the time phase flexibility the model therefore mostly resembles a physical model (fig. 16). We have originally implemented different temporal states according to the building history. But every building complex has its own particular history. Since there is too little information to show the whole process continuously over the centuries, the Pergamon model in the context of the excellence cluster TOPOI focuses on 200 AD to achieve one complete state in time. 200 AD is the most prosperous epoch: most of the buildings are erected and the least are destroyed (fig. 17).

Fig. 16 Pergamon 200 AD, acropolis hill. (Virtual photography of digital 3D model, 2011).

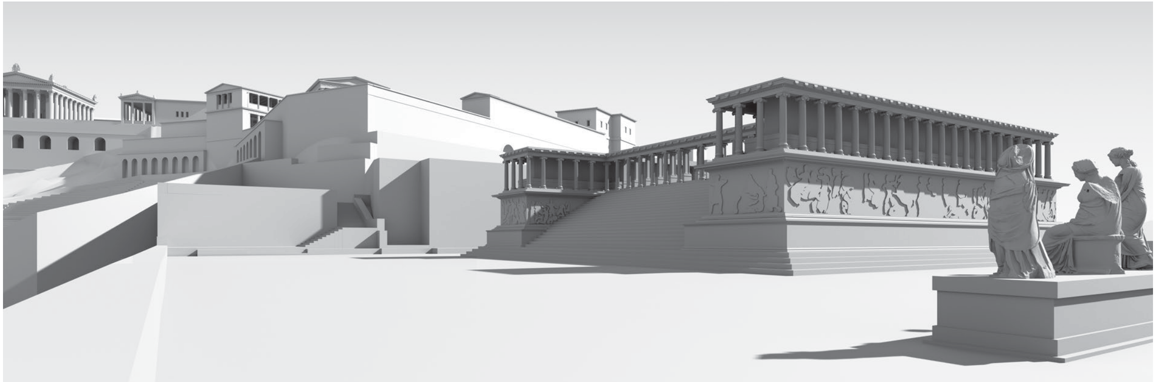

Fig. 17 Pergamon 200 AD, terrace of Great Altar. (Virtual photography of digital 3D model, 2012).

Left for further development is the transformation in time. The most important steps are: the ancient city on the mountain, the roman extension in the valley, fortifications from the byzantine time and the present-day town of Bergama (fig. 18). Before the mentioned decision to concentrate on one complete and detailed state, there have already been three different states of the model: the remains and two types of a reconstruction, a simplified one for overall city scapes and a detailed one for building levels (fig. 19).

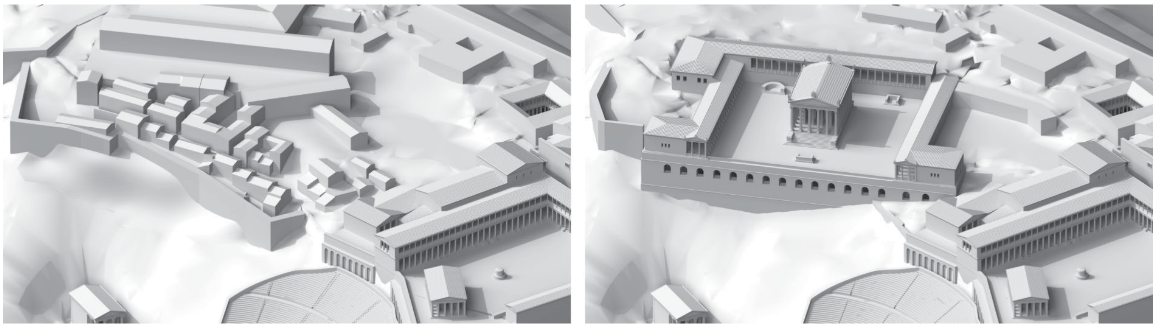

Fig. 18 Pergamon 200 AD, Traianeum and preceding buildings. (Virtual photography of digital 3D model, 2012).

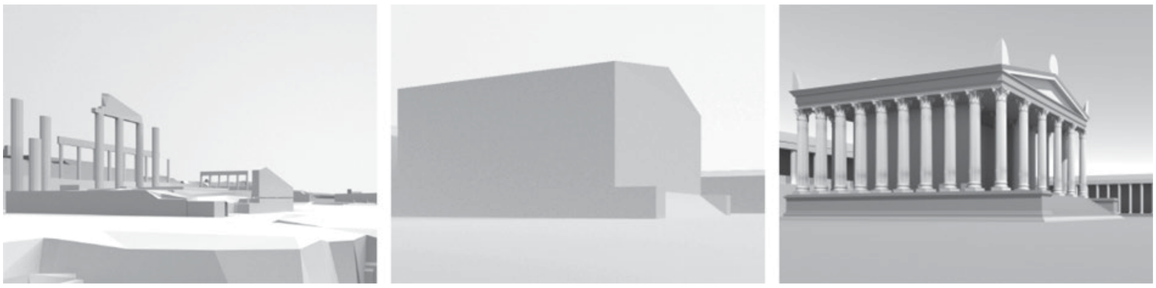

Fig. 19 Pergamon 200 AD, Traianeum. (Virtual photography of digital 3D model, 2009).

The model is intended for two different audiences. The first is the archaeological research itself. Having our model at hand on site, archaeologists hope to get impulses for their research, and to be able to develop and validate hypotheses instantly – with the remains visible in physical reality and their reconstructions in virtual reality (fig. 20). The second audience is the public. Our model is equally intended to promote the comprehension of the history of Pergamon in general as well as to explain the archaeological work as such to the public (fig. 21).

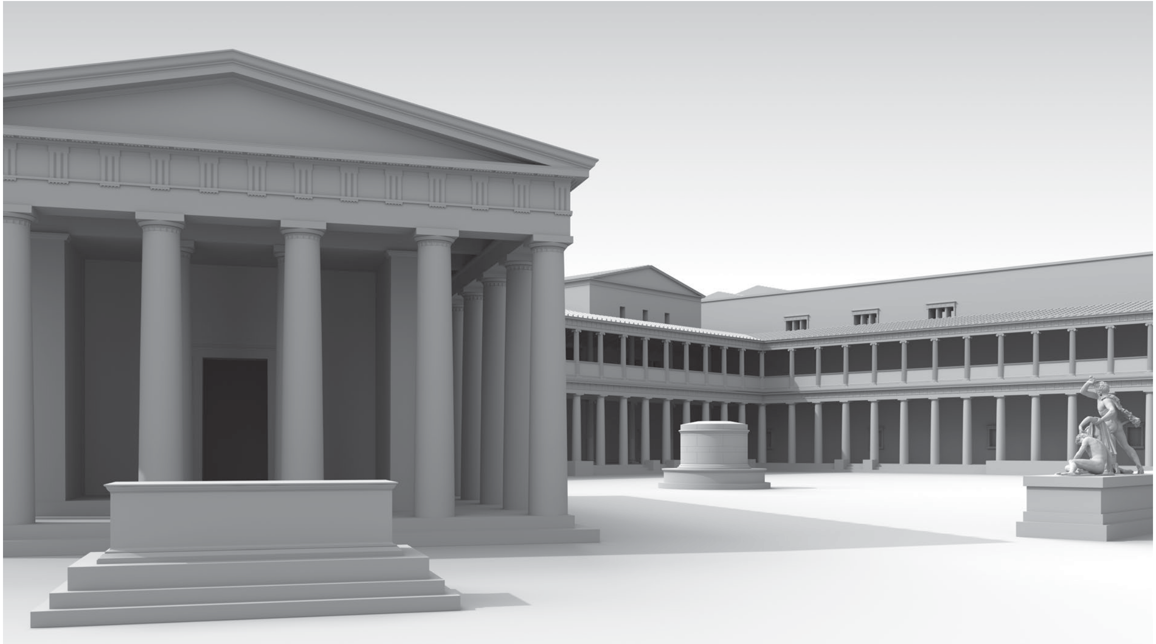

Fig. 20 Pergamon 200 AD, sanctuary of Athena. (Virtual photography of digital 3D model, 2011).

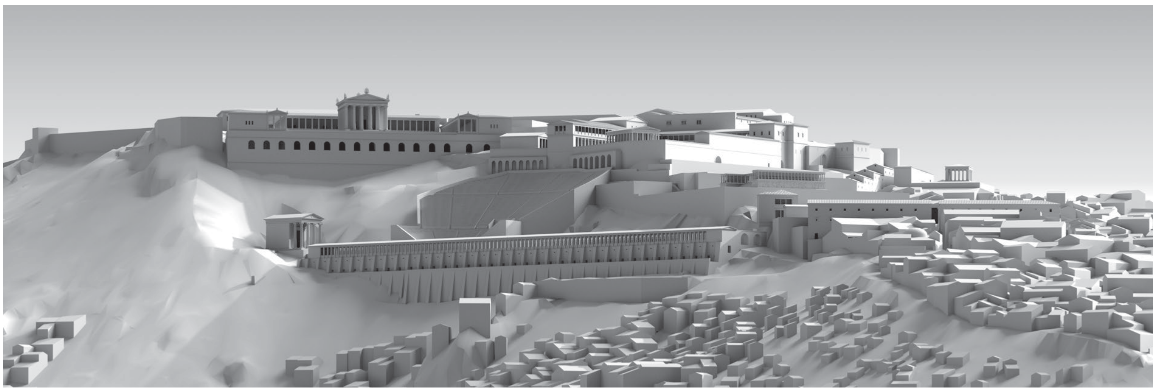

Fig. 21 Pergamon 200 AD, panorama from opposite mountain.
(Virtual photography of digital 3D model, 2012).

From September 2011 to September 2012 the current state of development is being presented at 'Pergamon. Panorama of the Ancient Metropolis', the first monographic exhibition about Pergamon at the Pergamon Museum Berlin since its inauguration in 1930.

Research Partners

Archaeology: Chair for Building History, Brandenburgische Technische Universität Cottbus-Senftenberg, Germany Archaeological Institute / Department Istanbul, Berlin State Museums – Collection of Classical Antiquities, University Freiburg / Institute of Archaeology (DFG-SPP 1209)

Measurement and model of remains: University of Applied Sciences Karlsruhe / Institute of Applied Research / Geoinformatics

Illustrations

Fig. 1, 8, 10, 12, 14, 16 Lengyel / Toulouse 2011*

Fig. 2–7, 13 Lengyel / Toulouse 2008

Fig. 9 Lengyel / Toulouse 2009

Fig. 11 Lengyel / Toulouse 2010

Fig. 15, 18, 21 Lengyel / Toulouse 2012*

Fig. 17 Lengyel / Toulouse 2012***

Fig. 19 Lengyel / Toulouse 2009**

Fig. 20 Lengyel / Toulouse 2011***

* in cooperation with the German Archaeological Institute, Prof. Felix Pirson.

** in cooperation with the German Archaeological Institute, Prof. Felix Pirson, remains by University of Applied Sciences Karlsruhe, Prof. Ulrike Klein.

*** in cooperation with the German Archaeological Institute, Prof. Felix Pirson, and Berliner Skulpturennetzwerk (Staatliche Museen zu Berlin, Freie Universität Berlin et al.).

Sharpness Versus Uncertainty in ‘Complete Models’[1]

Virtual Reconstruction of the Dresden Castle in 1678

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The main emphasis of the work in Darmstadt[2] is to create virtual reconstructions for exhibitions and research – remembering destroyed or lost architecture:[3] For example, the reconstruction of the Dresden castle, the reconstruction of German synagogues (fig. 9), the reconstruction of Chinese imperial tombs or the building history of the Kremlin in Moscow (fig. 3).

Fig. 1 Dresden castle, rendering 2011.

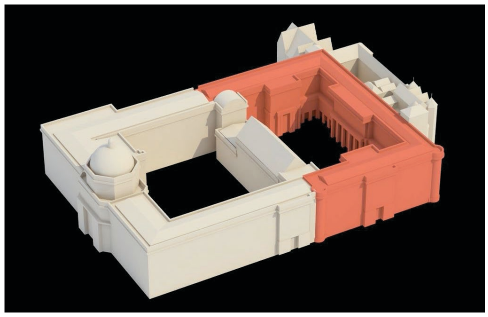

Fig. 2 Berlin Palace, rendering 2001.

On the one hand, these reconstructions cover didactic models, with the focus to explain different connections or aspects of research by showing the architecture in an abstract form. These connections could be the historical development of a building, the clarification of construction methods or the explanation of spatial connections and technical processes. The presentation of the Berlin Palace (fig. 2), the cathedral of Mainz (figs. 10, 13), different phases of the Dresden castle (fig. 16) or different designs of St Peter’s are examples for this (fig. 35).

On the other hand, different reconstructions were made in Darmstadt, where the emphasis was placed on an atmospherical effect of the model and a realistic presentation of the architectural space. Such atmospherical models try to convey a self-contained image of a building – so called complete models. They make up most of the Darmstadt projects. Examples within the topic of virtual palaces are the depiction of a royal apartment in the 16th century in the Hohkönigsburg (fig. 4), the Berlin palace (fig. 5), the Vatican Palace in the period of the High Renaissance (fig. 6) or the Dresden castle in 1678 (figs. 1, 7).

While didactic models identify uncertainties and knowledge gaps in many ways, atmospheric models show all parts in the same level of detail. Atmospherical models give the illusion of 'completeness'. Choosing 'complete' models is often a concept for the sake of a non-scientific audience. Consequently these atmospheric reproductions are normally the main attraction in exhibitions, but they are often criticized by art historians, building researchers and archaeologists. The quality of the presentation allows no conclusion as to the quantity and quality of the source materials. Therefore the developers have a great responsibility to fill the gaps by scientifically based speculations. In this case the model can be a contribution to a scientific discussion, especially if it is accomplished by a detailed documentation of the working process. Using the new virtual model of Dresden and its castle as an example it shall be demonstrated which values 'complete' models have as a knowledge transfer strategy for lost building structures. The main results of previous work are a rapid prototyping plaster print of the castle and its spacious surroundings, a virtual tour through the streets, courtyards and selected interiors of the former residential palace in 1678 and six digital models representing the building history of the Dresden castle.

In the following three topics connected to 'complete' models will be discussed. First, theses on the topic 'Sharpness versus Uncertainty'. Second, the intensification of this topic, using the Dresden palace as an example. Here the scientific research will be presented and it will be shown how the project dealt with the gaps. And third, the potentials of rapid prototyping models in context of uncertainty.

Fig. 3 Moscow Kremlin 14th century, rendering 2006.

Fig. 4 Baronial apartment Hohkönigsburg, rendering 2010.

Fig. 5 Schlüter court, Berlin castle, rendering 2011.

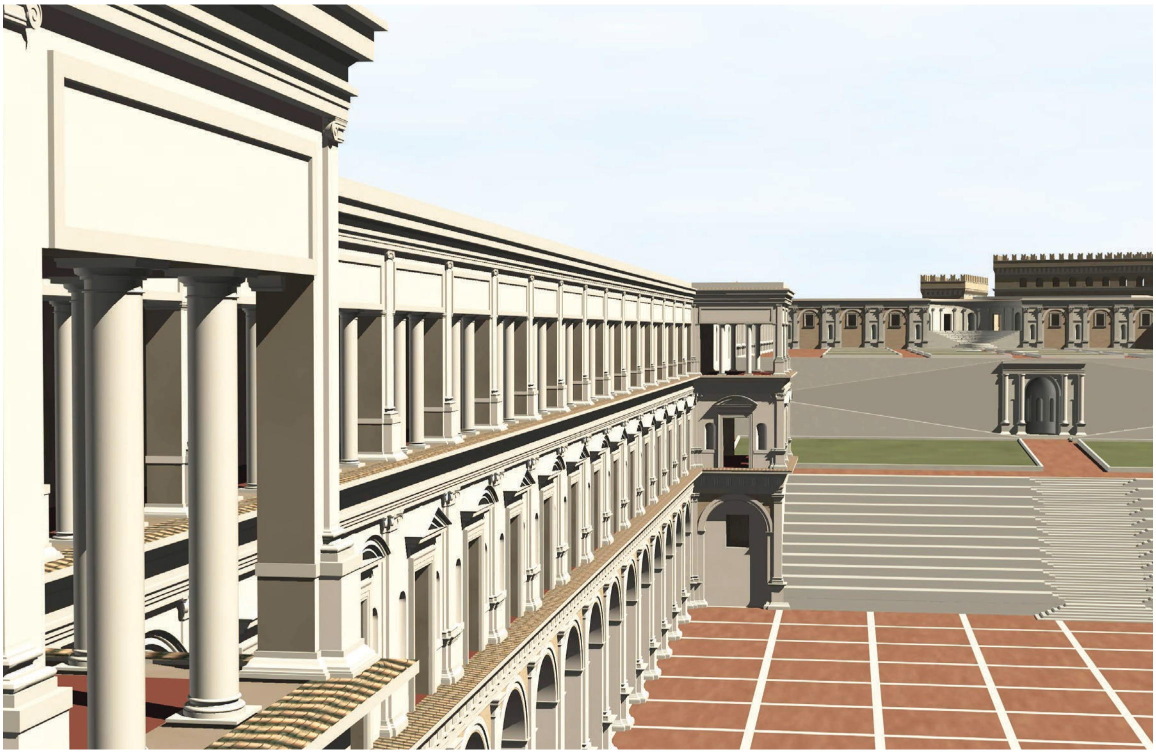

Fig. 6 Vatican Palace – ideal planning of Bramante, rendering 1998.

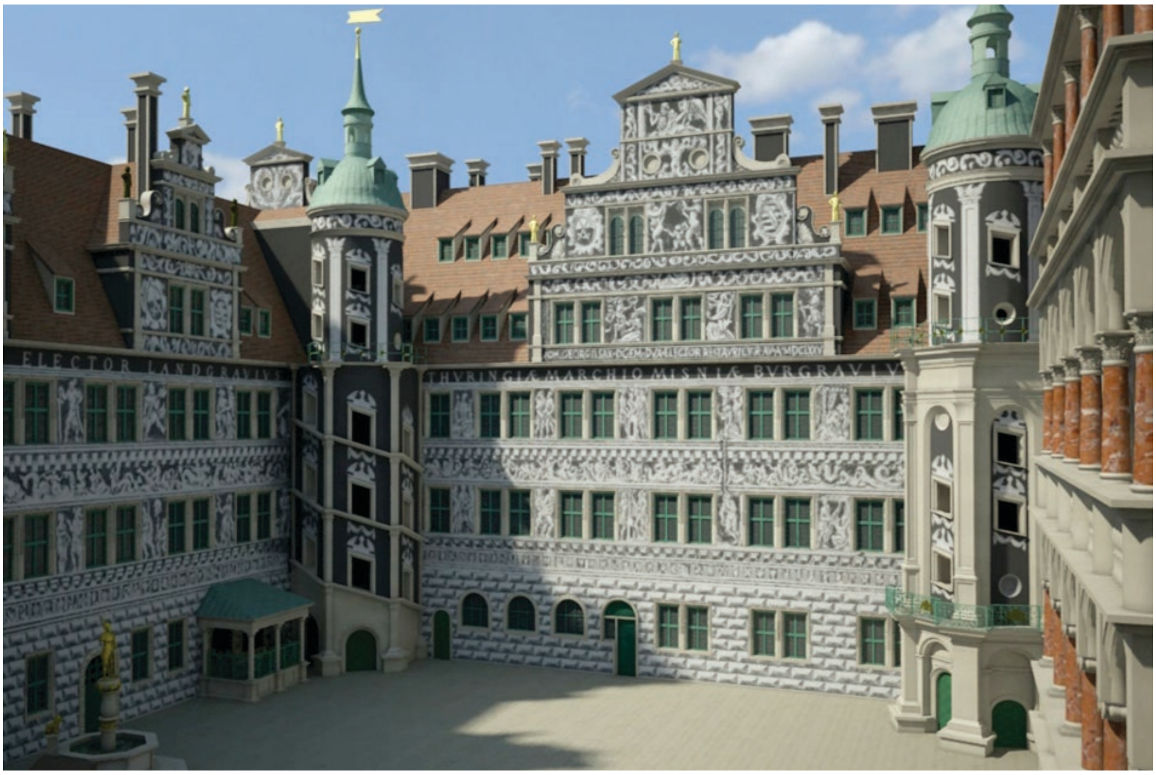

Fig. 7 Large palace courtyard Dresden, rendering 2011.

'Sharpness versus Uncertainty' in Complete Models

Complete models present a tremendous challenge. Here it is inherent in the system that solid knowledge and gaps are to be presented in an equal manner. The more realistic the models become, the more realistic also the facts that one does not know must be depicted. Images created this way are very powerful. Thus there is a special responsibility in dealing with these gaps and the filling of the gaps must be scientifically based. The additions must be done with the knowledge of historical architecture in accordance with the respective academic disciplines. A reconstruction should stand up to the claim of depicting a possible historic reality.[4]

How detailed or realistic a model is depends not only on the situation of sources and findings but also decisively on the budget. The sectors with large amounts of money – the game sector, movie industry and prime time TV documentaries have set the standards for many years. Here we also find 'living' models with people, animals, smoking chimneys, weathered façades and realistic landscapes. Clients and the public are aware of the technical possibilities. This leads to certain expectations and to a certain obligation to make reconstructions that look real. Such a trend is also noticeable in exhibition concepts.

For complete models, provocatively speaking, findings and sources have only a limited importance for the final representation: Reconstructions with a more extensive information basis and those with a limited one are relatively similarly presented. The figures show several Darmstadt projects with different basis of sources (fig. 8).

Fig. 8 Virtual reconstructions with different information basis, renderings 2002-2008.

In our opinion, it is scientifically absolutely necessary that in the case of complete models solid knowledge and reconstruction derived from sources could be comprehensive. However, this doesn't have to be automatically evident in the presentation. And it is not just only the decision of the person doing the reconstruction or the person who is the scientific advisor but often the decision is made by the client.

To give these complete models a scientific relevance, a comprehensive documentation is important, including the description which sources, fundamentals and decisions lead to which solutions. If one supplements this with the protection and safekeeping of primary data as well as scientific publication – criteria for good scientific practice set up by the DFG – the German Research Foundation – there can be a great variety of opportunities in dealing with uncertainty.

This range consists of:

- Complete models without references to gaps (fig. 9)
- Different degrees of detail in the geometry and surface (fig. 10)
- Various graphical solutions of individual areas in the model according to certainty (fig. 11)
- Written or spoken text to make one aware of gaps
- Overlaying with remaining structures (fig. 12)
- Alternative reconstructions (fig. 13)
- Finally the inclusion of sources, basics and analogies in the presentation (fig. 14)

Fig. 9 Synagogue Frankfurt Höchst, rendering 2010.

Fig. 10 Mainz Cathedral, rendering 2009.

Fig. 11 Old St Peter's, rendering 1998.

Fig. 12 Medieval Synagogue Speyer – site and virtual reconstruction, rendering 2004.

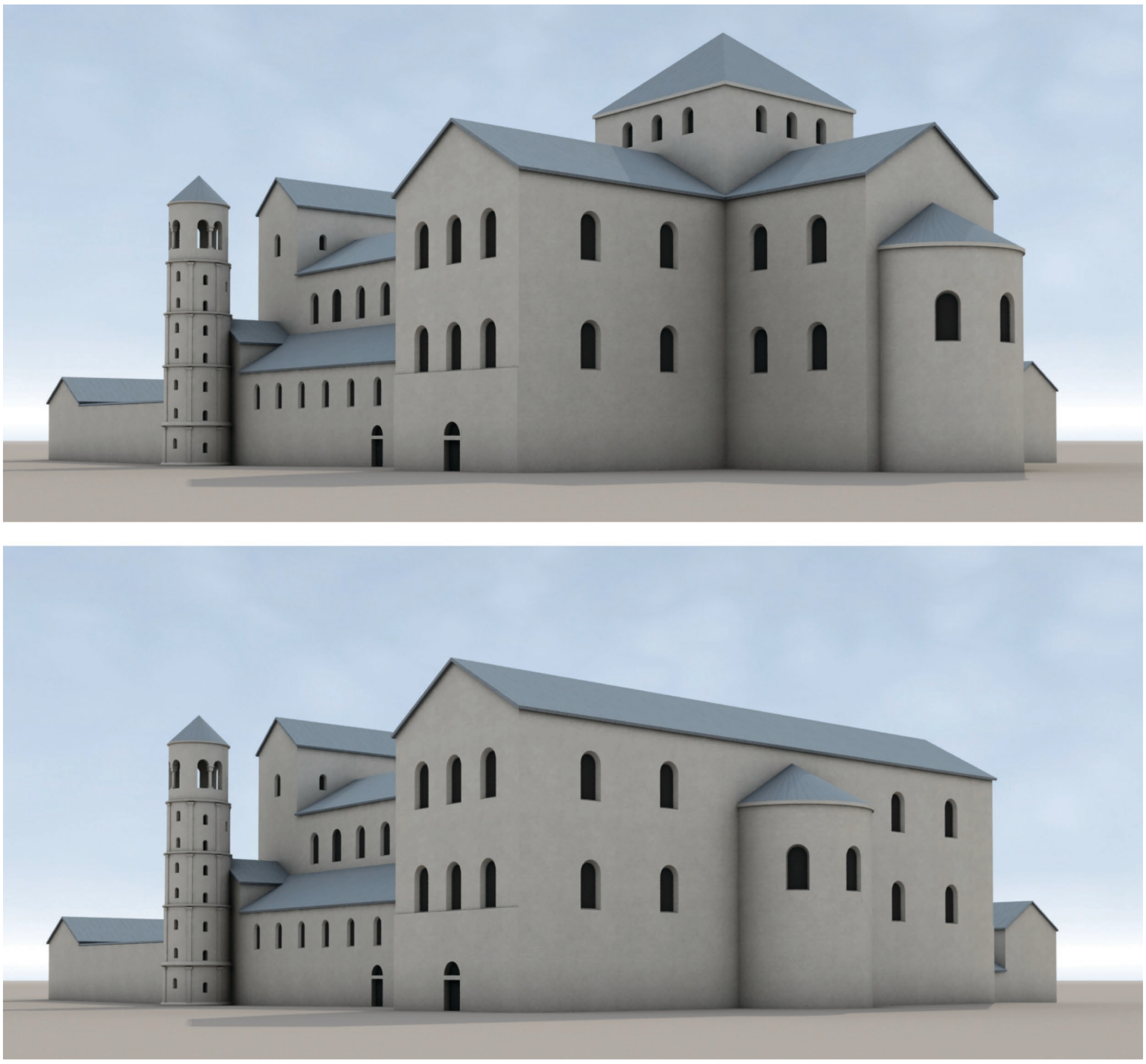

Fig. 13 Different solutions for the Romanesque phase of Mainz cathedral, renderings 2009.

Fig. 14 Various sources for the virtual reconstruction of the Carolingian imperial palace at Frankfurt, renderings 2008.

With reservations, however, it can be ascertained that the aforementioned scientific practice seldom can be maintained. Time is one important factor and thus also the cost. This is particularly true for non-university work, whereby as a rule documentation is not asked for and thus not paid for. Furthermore, so far no standards for documentation have been established.[5]

There is another basic problem that one can hardly ever avoid: Regardless what one shows, an idea is conveyed. The elimination of details is also the conveyance of a false picture. Thus the usual practice not to even show parts of a building is a good strategy that is reconcilable also with complete models if they are represented by films or pictures. And if one wants to emphasize the uncertainties then this should definitely be done in an aesthetical and satisfying graphical presentation.

Nonetheless, complete models only make sense when the aim is to show the cultural, the heritage value or the beauty of lost architecture. For many projects a didactical abstract model is more sensible, not least because much more time and money has to be invested in complete models. In the end, from a scientific point of view the realization of a complete model is the more fascinating approach, because it satisfies the thirst for knowledge and the exploratory urge. One is challenged to find out things that were not thought of before and to study analogies and sources and to compare them. This was done for the reconstruction of the Dresden castle and it is an example of how to deal with the gaps in a project and how it could be documented.

Virtual Reconstruction of the Dresden Castle

In 2008 the Staatliche Kunstsammlungen Dresden asked the Technische Universität Darmstadt for a digital and a haptical model of the Dresden palace and its surroundings in the appearance of 1678. The area to be represented covered the Royal Palace and its urban surrounding of about 21 ha (fig. 15). Beyond the residence buildings, like the castle, the office building, the stable yard and riding school, the model includes the fortifications to the river Elbe in the north as well as numerous town houses.

The origins of the Dresden castle date back to the 12th century (fig. 16). The oldest preserved building fabric in the rising walls remained from about 1400 in the north wing and the Tower (Hausmannsturm). Since 1485, it became the permanent residence of the Albertine line of the house of Wettin. The residence castle had already been extended to a quite modern four-winged complex by the middle of the 16th century. It remained more or less without structural alterations up to the end of the 17th century. After a fire in 1701 it was gradually transformed into a baroque style. Further profound changes took place in the 19th century initially with the redesign of the banquet halls and parade rooms. At the end of the 19th century the building was also changed in its outward appearance by the uniform design of façades in Neo-Renaissance forms. On 13 February 1945 the complex was seriously damaged during the bombing of Dresden and almost burned completely.

The Staatliche Kunstsammlung Dresden as the client has chosen to demonstrate the year of 1678 not because of a significant architectural stage but because of excellent source material. There are two comprehensive copper engraved works, which were a good basis for a reconstruction. In 1678 the festival culture at the court of John George II in Dresden culminated in the 'Durchlauchtigsten Zusammenkunft', a family meeting of the Albertine line of the House Wettin (fig. 17). The Councilor Gabriel Tzschimmer was commissioned to compose a report, which was illustrated with 30 large-sized engravings.[6] Thus the focus of the presentation was not the lifelike reproduction of the architecture but the splendid depiction of the procession.

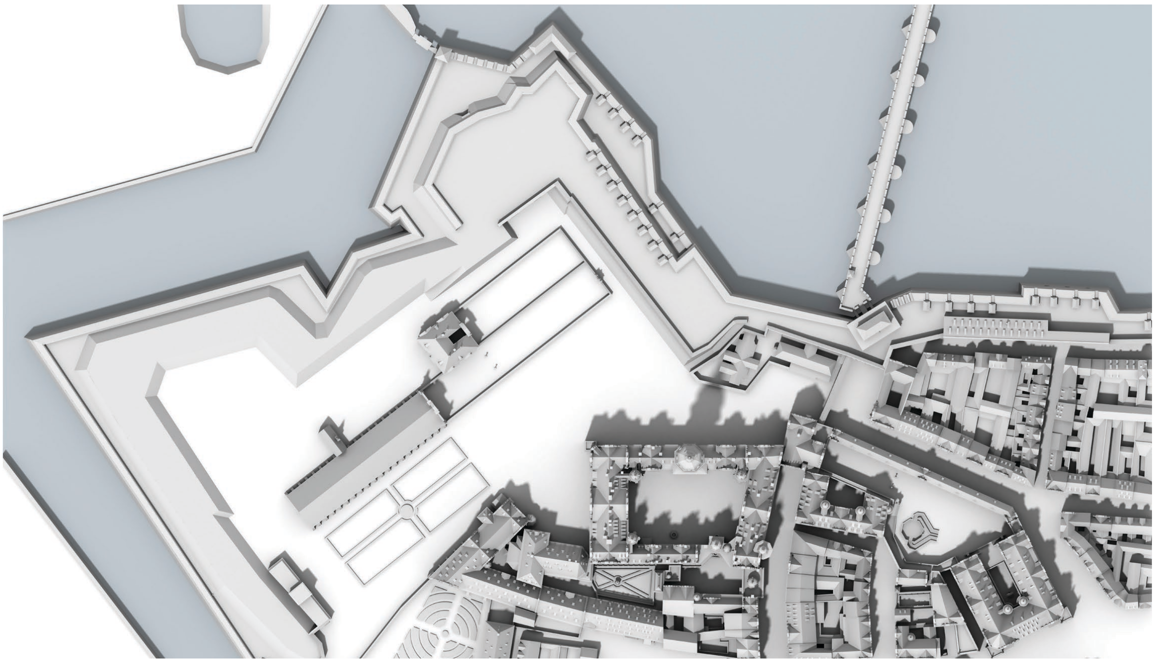

Fig. 15 Digital template for the haptical model, complete sector of representation, rendering 2011.

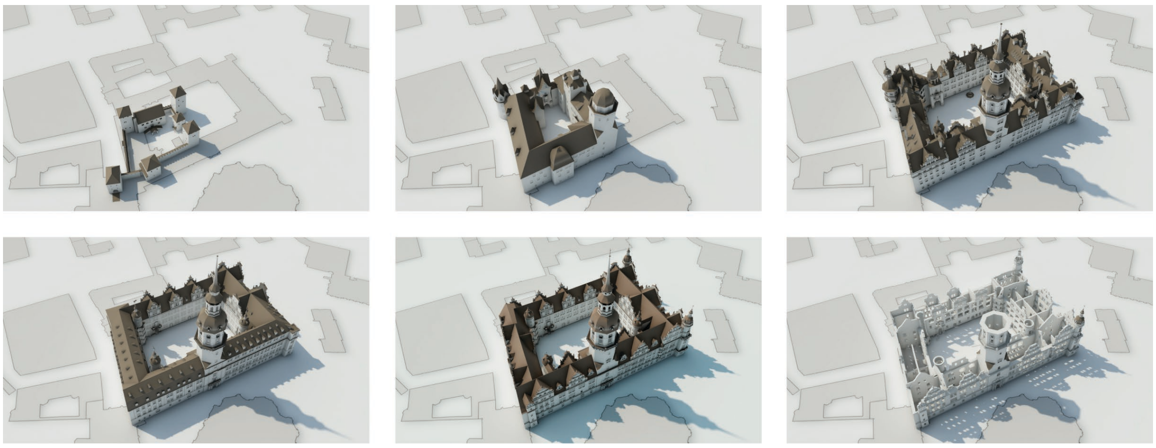

Fig. 16 Six building phases of the castle: 13th century, 1535, 1678, 1768, around 1900, 1945, rendering 2011.

Fig. 17 The street Schlossstraße with the gate house to the Small Castle Courtyard.
Extract of a copperplate from G. Tzschimmer, 'Die Durchlauchtigste Zusammenkunft', 1680.

The chronicle of Dresden, *'Der Chur-Fürstlichen Sächsischen weitberuffenen Residentz- und Haupt-Vestung Dresden Beschreib- und Vorstellung'* (fig. 18), has a very different background. It was written by Anton Weck and published in 1679 in Nuremberg. The author deals with the development of the city up to the 17th century, but with emphasis on a description of the status quo. The text is illustrated by numerous engravings, representing the royal architecture in detailed views. In order to evaluate the authenticity of the depiction, it may have to be taken into account that the work was commissioned by the Elector with the aim to gain honor and glory.[7]

The research for the virtual reconstruction was founded on a comprehensive study of professional literature and the cooperation with archivists, architectural historians, archaeologists etc. It was not the task to analyze written primary sources. However it was advantageous that there exist profound scientific works, like a compendium about the fortification of Dresden or the numerous contributions to the architectural history of the castle.[8] Beyond the engravings all available image sources were collected, which show buildings of the relevant time, for example historical paintings, drawings and pictures of historic models. Therefore maps from the time before 1678 were analyzed in order to select information about buildings and urban elements which remained until the year 1678. In the same manner pictures of later times were collected and examined if they depicted elements of the relevant time and how they had changed since. Eventually the collected stock consisted of more than 800 pictorial sources to support the design of the model.[9] An exact source analysis and founded critique were essential for the interpretation of the documents.[10]

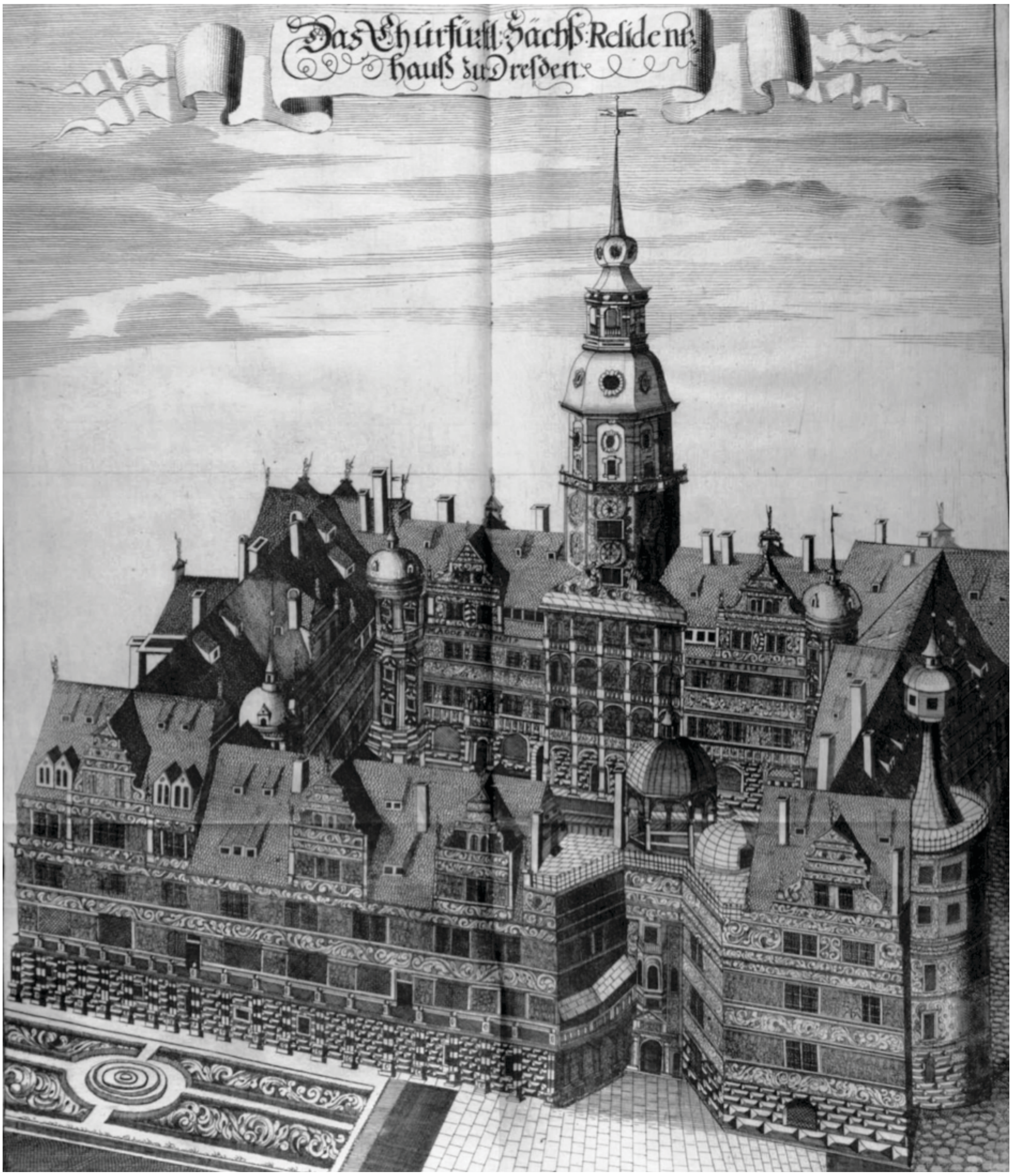

Fig. 18 The Castle from a bird´s eye perspective. Copperplate by Anton Weck, *Der Chur-Fürstlichen Sächsischen weitberuffenen Residentz- und Haupt-Vestung Dresden Beschreib- und Vorstellung*, Nuremberg 1680.

The whole material was digitized and catalogued, sorted by the certain buildings and completed with instructions for the usage (fig 19). Important buildings with a lot of source material got a compendium, which contains not only main information about the building history and design phases but also detailed information about the sources. All stakeholders got access to the catalogue with the required information. It was the main basis for later discussions about the building history and its appearance in the period under consideration.

Großer Schlosshof, Nordfront	Repro aus: Das Königliche Residenzschloss zu Dresden, Verlag Römmler & Jonas, Dresden 1896, Tafel 6		Römmler&	1896, um	1896		Foto, Lichtdruck			Repro LfD	LfD	h_nof_1896_170
Georgenbau												Dateiname
Das alte erbauete Schlosz zu Dresden von Herzig Georg zu Sachsen	beide Fassaden des Georgentores		Wecks Be	1678	1678	BZ	Kupferstich		SLUB, KS B4260	df_dk_0002635	SLUB	s_geb_1680_074_b; s_geb_1680_74
Pläne mit Umgebungsbebauung Schloss												Dateiname
Dresden vom linken Elbufer oberhalb der Augustusbrücke			Bernardo	1748	1748		Gemälde		Galerie alte Meister		SKD-G	Ausschnitt: u_spl_1748_066_b
Das Ringrennen des Karusells der Vier Elemente im Zwingerhof am 15.9.1719	Vogelschau auf den Zwinger		C.H.J.Fehling		1719		Federzeichnung			GG	KuKa	u_zwi_1719_063_b
Fassade des Stallgebäudes Christians I. zum Jüdnhof aus Tzschimmers "Die Durchlauchtigste Zusammenkunft"	persp. Ansicht		Tzschimm	1680	1680		Kupferstich				KuKa	u_sge_1680_087_b
Umgebungsplan des Stallhofes mit dem Stallgebäude, Georgenbau und Kanzleihhaus	Grundriss		P. Buchne	um1591	1591		Tusche			GG	LfD	u_sho_1586_062_b, u_sho_1591_178
Der Stallhof unter Christian I.	Ansicht Lnger Gang bis Fassade zum Jüdenhof			1586	1586						LfD	Foto: u_sho_1586_212
Die Schlossstraße mit der Gasse am Taschenberg, den südlich des Schlosses gelegenen Renaissancegebäuden und dem Torhaus zum Kleinen Hof	Persp. Ansicht		Tzschimm	1680	1680		Kupferstich			Bild im LfD, Lit: „Die Dresdner Straßenansichten" 1678, Tafel E	KuKa	Scan von Foto (Ausschnitt): s_osf_1678_181
Die Armbrust- und BüchßenSchützen-Aufzugk aus der Raths zu Dresden Schieß-hauße durch die Schießgasse	Schießhaus mkt Schießgasse		Tzschimm	1680	1680		Kuperstich		SLUB Kartensammlung, KS B1587	df_dk_0001510	SLUB	u_sch_1680_123
Aufzug der Wagen zum Ringrennen der Damen am 6. Juni 1709	Ansicht des Schlosses von NW mit den davor befindlichen Festbauten, Reit-und Schießhaus		C.H. Fritzs	1710	1710		Deckfarben			C 1968-791	KuKa	u_sch_1710_064_b, u_sch_1710_064
Stallgebäude nach dem Umbau 1730/31	Persp. Mit Ansicht der Nachbarbebauung		M.Bodene	nach 1731	1731		Kupferstich			Sax.top.11,222	KuKa	u_sge_1731_061_b
italienisches Dörfchen und Umgebung				nach 1756	1756		farbig		304/1966	(M=50010955)	LfD	u_itd_1756_001_s
italienisches Dörfchen und Umgebung				um 1756	1756		farbig			M.10.IV.Bl.34 (M=50005	LfD	u_itd_1756_002_s
Sophienkirche mit Umgebung				um 1750	1750		farbig		Dresden 1/215	M10.cl.Bl.5 (M=50001 7	LfD	u_ski_1750_007_s
Sophienkirche mit Umgebung				um 1753	1753		farbig			M1.cl.Bl.3 (M=50000 55	LfD	u_ski_1753_008_s
Ansicht des Klosters und des Schlosses von Süden	perspekt. Skizze											u_klo_xxxx_023_s
„Comoedienhaus" von 1667			Gurlitt	1901	1901		Tusche			aus Gurlitt		u_koh_1667_054_b
Komödienhaus	Grundriss und Schauseite, wahrscheinlich Rekonstruktion von Bachmann für Zustand 1664 nach Plänen des HstA			Reko von	1667					Bildsammlung	LfD	u_koh_1667_207
Ballhaus von 1598, Grundriss und Schnitte			Gurlitt	1901	1901		Tusche			aus Gurlitt		u_bah_1901_057_b
das churfürstliche Ballhaus von 1668	nicht das klengelsche Ballhaus, evtl. das von 1598, Rekonstruktion wahrsch. von Bachmann, vgl. auch die Zeichnung bei Gurlitt: u_bah_1901_057_b			evtl. Rko v	1598					LfD Bildsammlung	LfD	u_bah_1598_211
Blick auf Hofkirche, Georgentor und ital. Dörfchen von Nord-Ost			C.W. Arldt	um 1833	1833		Lithogr			Sax.top. III,2	Kuka	u_khk_1833_065_b
Das Residenzschloss mit Umgebung	nach den Originalaufnahmen des Feldmessers Langer von 1694		Gurlitt	1901	1901		Kopie			aus Gurlitt		u_sbz_1901_077_b
Stallhof, NW-Ecke mit Langem Gang und Georgenbau			Gurlitt	1901	1901		Kopie von Foto			aus Gurlitt		u_sho_1901_078_b
Aufriß des Stallgebäudes	mit Maßen,			Um 1743	1743		Tusche	388x527	Kuka, Sax.top.II, 2, 28	C 4280	Kuka	u_sge_1743_099
Plan et Elavation des Ecurie Roiales à Dresde	Fassade des Stallhofgebäudes zum Jüdenhof nach dem 1. Umbau 1729/30 durch Pöppelmann		Glässer, A	Nach 173	1730		Kuperstich	192x298	KuKa, Sax.top.II	A 131511	KuKa	u_sge_1730_101

Fig. 19 Section of the Excel file with the catalogue of picture sources.

The processing was split into two scientific disciplines, on the one hand the historical building research and on the other hand the data processing and model construction.[11] On the basis of the available maps, pictures and written information a proposal was made for the reconstruction which was corrected and evaluated with a view to the architectural history (figs. 20-21). It also appeared that some of the scientific theses were not working in the three-dimensional space. Thus a rather inspiring dialogue came up among the different stakeholders. The discussions and decisions were documented by hand. It will be the challenge for the future to publish the developing process to a scientific audience.

As might be expected, there was no complete information available to the former appearance of all buildings. But even for the well-documented structures, such as the 'Schießhaus' (shooting house), there were gaps in knowledge, which concerned parts of the buildings, and sometimes also the existing documents were contradictory. Since the task was to create a complete model for the exhibition, the knowledge gaps had to be closed in the representation, which means to align parts with high and low density of findings.[12] It was the aim to ensure a high scientific level in filling the gaps. Thus for certain cases different strategies were used, which are explained below in more detail, based on four selected examples.

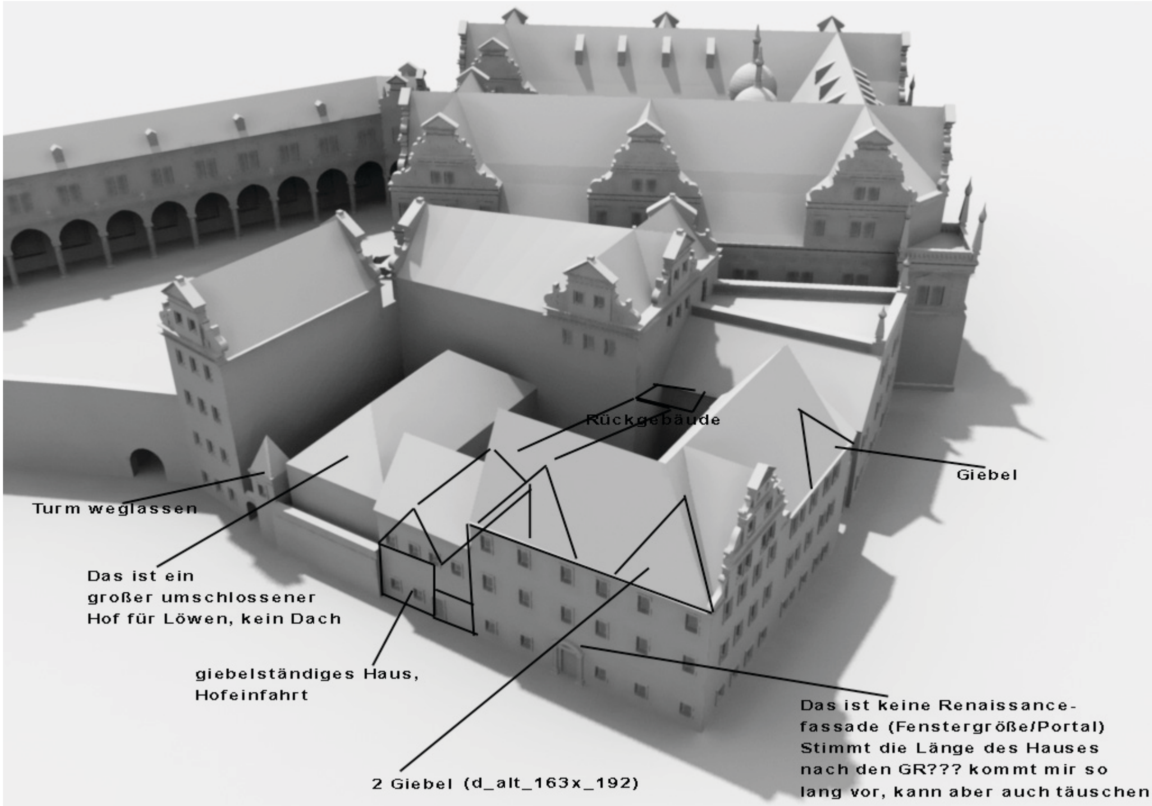

Fig. 20 Proposed corrections during the work process, screenshot 2010.

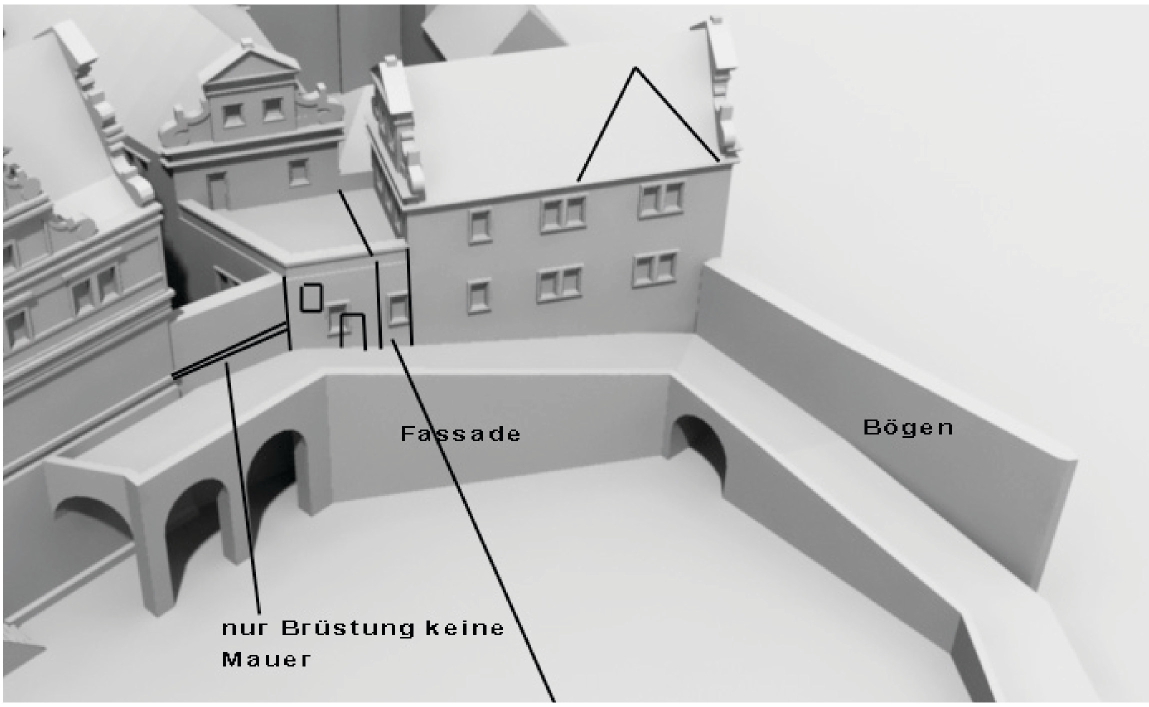

Fig. 21 Proposed corrections during the work process, screenshot 2010.

Filling Gaps by Complementation of Fragments / Retouch

First the interior of the chapel should be considered. One gets the best impression of the historic appearance from two engravings from the years 1676 and 1730 (fig. 22). They were the main basis for the reconstruction. Moreover, there are floor plans and sections as well as photos of a 16th-century model of the palace, in which the chapel is shown. Parts of the exterior walls are preserved in situ. A lot of information could be taken out of a recently published book,[13] which summarizes the state of research. But still the reconstruction of the twined rib vault with figurative sculptures was a big problem.

The SIB (state-owned real estate and construction management company) had established an interdisciplinary group of scientists to make a new proposal for the figuration of the former vault in order to prepare the real reconstruction.[14] They tried to imitate the historic process of the construction and transferred it to a digital model, which we could use for our work. But the comparison with the copper engraving shows that the vividness is lost without the sculptures (figs. 23-24). These sculptures are also mentioned in a written source of 1629, which describes the snakes and ghosts, standing for the guilty pleasures. Putti are fighting them with the instruments of Christ´s torture.[15] These sculptures are only known from unprecise pictures and two small remnants of the snake bodies, which were found in the ruins after World War II. No comparable decorated twined rib vault is known of. The only information was applied to a new image of the lost design. The method is comparable to the retouch, known from conservation praxis.

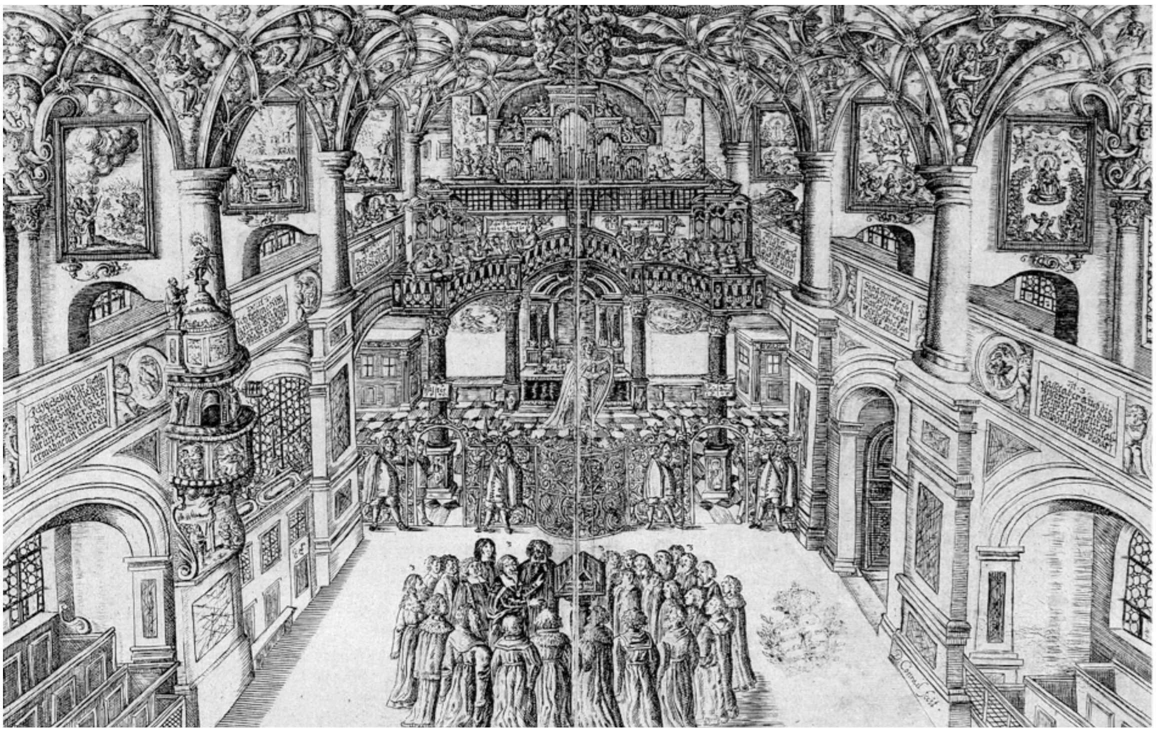

Fig. 22 Interior view of the castle's chapel. Copperplate by David Conrad, 1676.

The representation of the vault without the sculptures would have distorted the appearance as it is known from the engravings. First, all known elements, such as the ribbed vault, were reconstructed and in a second step the missing elements were fitted in. The aim was to create an image that matches the historical illustrations as much as possible.

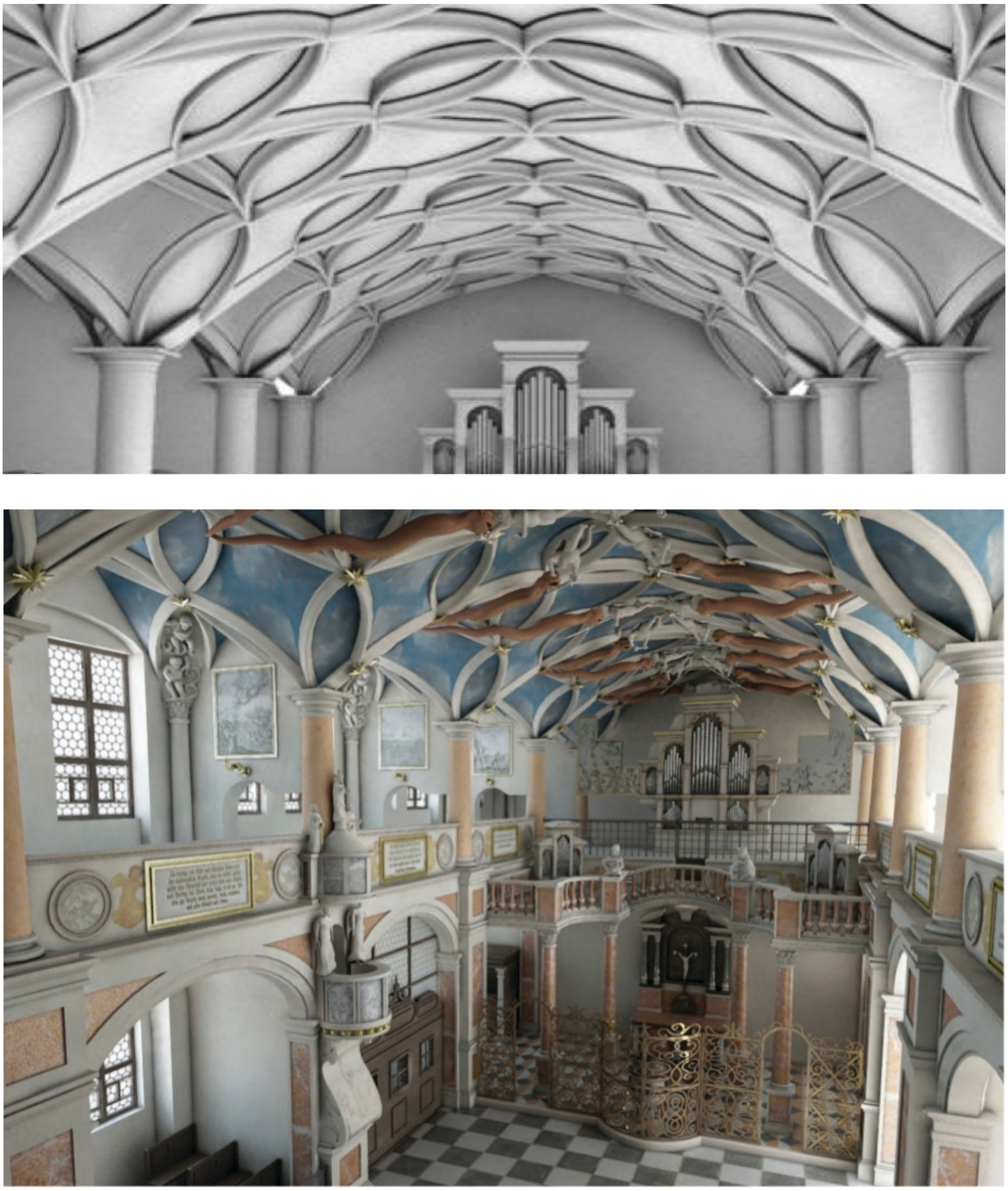

Fig. 23 and 24 Detail from the virtual reconstruction of the chapel, without the sculptures at the vault (top) and final state, screenshot and rendering 2011.

Filling Gaps by Composition of Complemented Fragments

Beside the supplementation of whole missing elements the possibility to complement certain elements / partitions and compose them to a complete picture should be considered. The virtual reconstruction of the hall of giants should serve as an example (fig. 25). The hall was famous for the larger-than-life representations of the giants and the pictures of Saxon cities above the windows and the vault with the zodiacal signs (fig. 27).

Two coloured pictures of the year 1693 show the interior, designed by Wilhelm Dilich in the first half of the 17th century (fig. 26).[16] Both gouaches and another known engraving from the report of Gabriel Tzschimmer show the view south into the hall. With the foreshortening of the perspective the density of information decreases. For the vault an original coloured design plan of Wilhelm Dilich could be used, which allowed the calibration of the colours in the digital model according to the historic paintings.[17] The reconstruction of the city views was more complex, even though the iconography of the pictures is known. Most of the city views are submitted from original sketches of Wilhelm Dilich, but they lack colouring and also foreground figures. To approach the appearance of the gouaches the decision was made to colour these sketches by hand (fig. 28). The foreground figures were cut out of the historic painting, rectified and added to the reconstruction. In some pictures they had to be omitted because of the foreshortening of the perspective. Also all the other parts of the ceiling, like frames and cornices, were reconstructed and supplemented based on the existing information. At the end the entire virtual ceiling design was completed due the merging of the individual sections.

Fig. 25 Detail from the virtual reconstruction of the hall of giants, rendering 2011.

Fig. 26 General view of the hall of giants during the Order of the Garter award procedure.
Gouache by J. Mock, 1693.

Fig. 27 Detail from the virtual reconstruction of the hall of giants, rendering 2011.

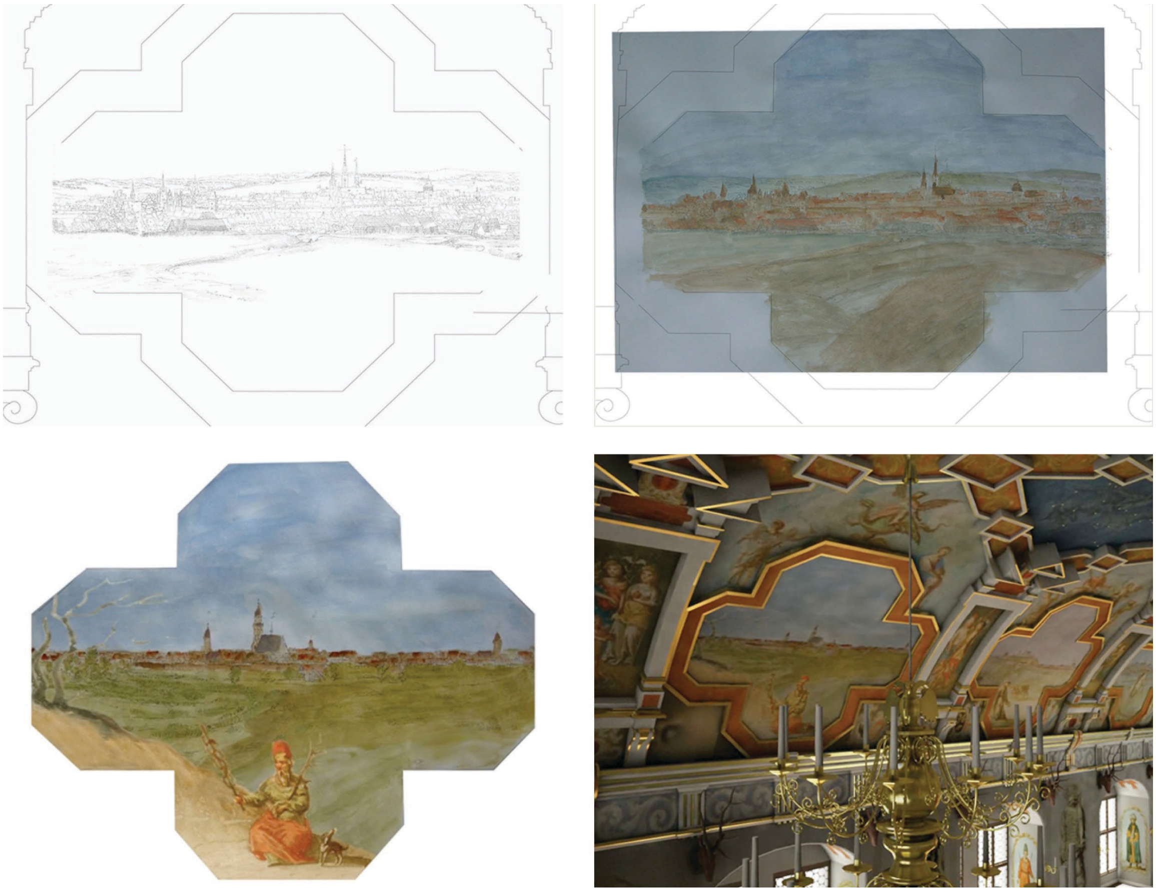

Fig. 28 Designing process of the cityscapes in the hall of giants for the virtual model.

Fig. 29 Detail from the virtual reconstruction of the hall of giants with the city scapes, rendering 2011.

Filling Gaps by Analogy and Copy

A third example leads to the exterior. As the castle is documented by a huge amount of source material, the gaps in a certain scale are not that enormous. The situation of the middle class houses is completely different. Even in the second half of 17th century the presented quarters are characterized by the Renaissance period, because there was a low construction activity during and after the Thirty Years' War. The clients' task already distinguished between the royal buildings as the castle, the stable yard and the theatre on one side, and the townhouses on the other side, which should be designed in a more simple way. The destruction of the whole centre of Dresden in World War II was so enormous that there are hardly any middle class buildings of the 17th century left. Only for very few buildings there are plans and documents which show the state of 1678. For some of the buildings it was possible to take over at least certain parts from later depictions and photos. Some façades were designed according to the two already mentioned copper engraving works. Here it was necessary to review the validity of the pictures, i.e. the geometrical exactness, the level of abstraction or the right location of bays and doors.

Other buildings are only known by a bird's eye perspective from the year 1634, i.e. 40 years earlier. But still for a large number of town houses we have no information at all beyond vague town plans. Therefore a lot of house façades were reconstructed by analogies and copies. Beside the pictures of Dresden buildings, also existing middle class houses of other Saxon cities like Freiberg and Meißen were used as a comparison. Whole façades or single architectural features were transferred to fill the gaps (fig. 30).

Fig. 30 Still of the virtual tour showing the street Schlossstraße with the castle in the background on the left, rendering 2011.

When using analogies and copies, it is important to take into account an individual trait of the structures as well as known. That means a palace of the late 17th century should not get a Renaissance-façade or look like a farmer's townhouse. In order to avoid a misleading monotony we put emphasis on the design of known characteristics. For example the so-called Löwenhaus (Lion House) possessed a huge yard with a surrounding gallery, which was probably the lions´ enclosure.[18] This special architectural structure was adopted in the reconstruction (fig. 31).

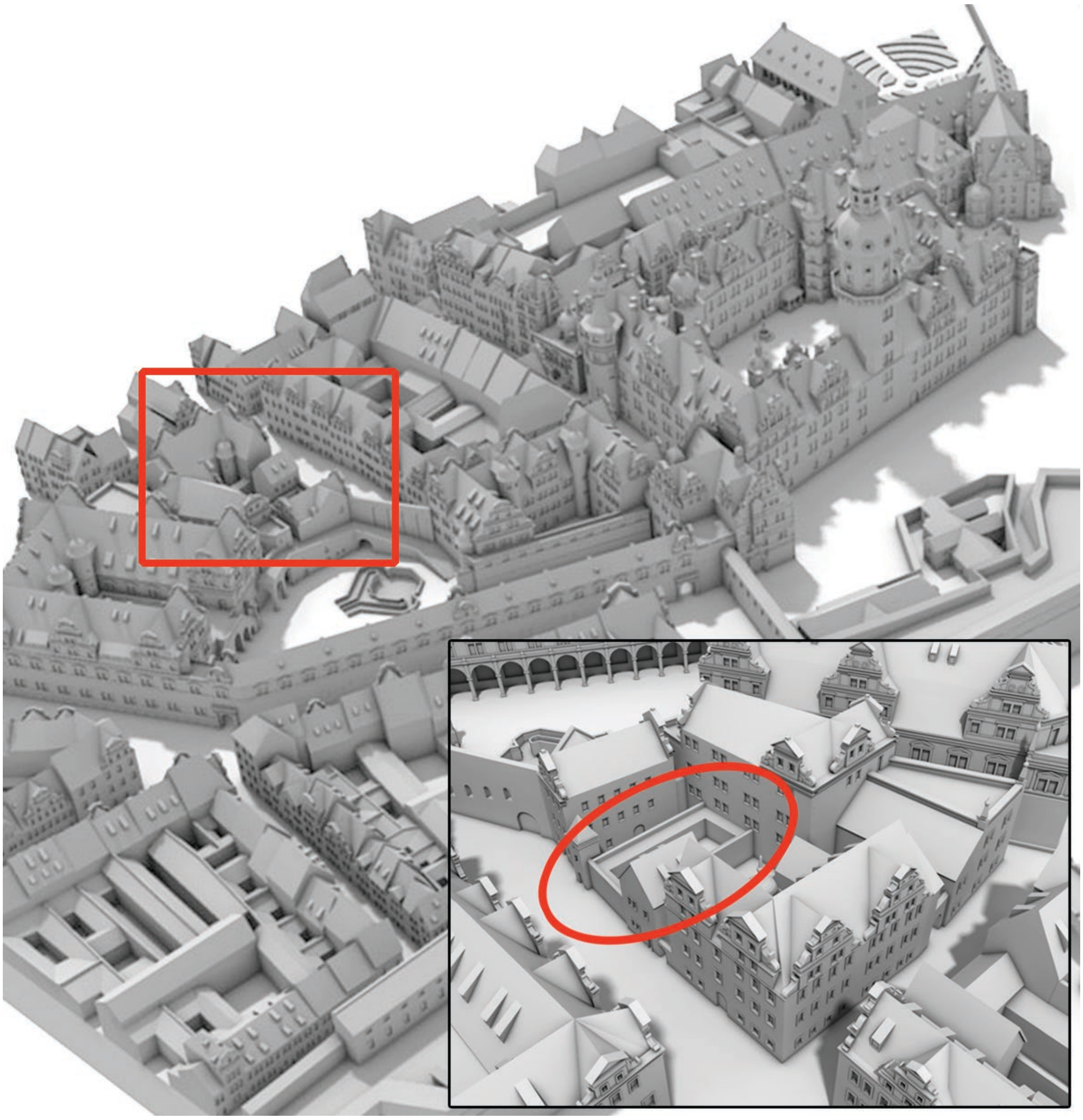

Fig. 31 Detail of the digital template for the haptic model with the so-called 'Löwenhaus' (Lion House), screenshot 2010.

Filling Gaps by Abstraction

While the source material for the street façades is fragmentary already, for the courtyard façades only isolated references to their original appearance were found. Furthermore, there are no examples of 17th-century courtyards preserved in Dresden. Comparable structures don´t even exist in other Saxon cities anymore. As a consequence to this lack of information, the team decided to show these back façades in a higher level of abstraction and abstained from showing details like windows and doors (fig. 32).

As it was demonstrated, there are several ways to close knowledge gaps in a virtual reconstruction and thus to make them invisible. Thereby a complete image of past architecture is generated. But the problem remains in the mediation of these images, because the representations are often seen as an image of the real past. In truth, however they are only one possibility among many and are furthermore linked to time, place and editors of its manufacture.

It is therefore the responsibility of the stakeholders, to perform the reconstruction as well as the contained supplements on a scientific basis. Equally important is an appropriate manner of presentation that allows an assessment of the source material and the degree of information density. If this is not guaranteed, one has to put up with the accusation of Disneyization.

Fig. 32 Detail of the digital template for the haptic model, houses at the Neumarkt with the abstract courtyards, screenshot 2010.

Rapid Prototyping Models

As mentioned above the task for the Dresden project was not only to create a virtual reconstruction but also a haptic model. For a long time, one had to decide between a 3D computer reconstruction or a haptic model. Now with few additional costs one can realize both. Thus one can present at the same time computer models and real models and can unite the advantages of both of these forms of presentation. In Darmstadt University, technologies from industrial prototype construction, which allow to produce haptic models from digital models economically and in the shortest period of time, have been used for several years already (figs. 33-34). Examples of such haptic models produced in Darmstadt are the models of St Peter's (figs. 35-36), the reconstruction of the imperial palace in Frankfurt during the Carolingian time, the bell tower of the Moscow Kremlin at the time of the early 16th century. For Dresden the rapid prototyping model measured 2,20 × 1,35 m. The model of the landscape was milled, the buildings fabricated in plaster printing and placed on the board (figs. 38, 40).

Fig. 33 Process 3D printing, 2005.

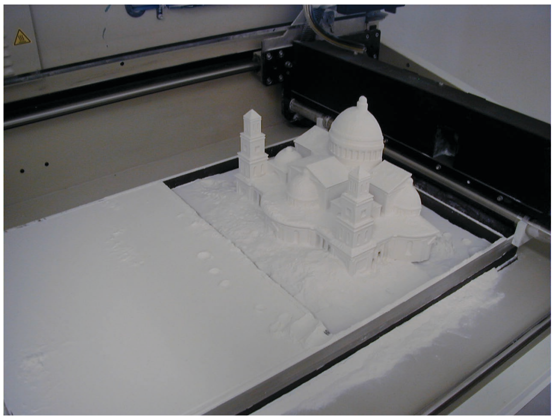

Fig. 34 Printed model, 2005.

Fig. 35 Virtual model St Peter (Michelangelo), 2005.

Fig. 36 Rapid prototyping model, 2005.

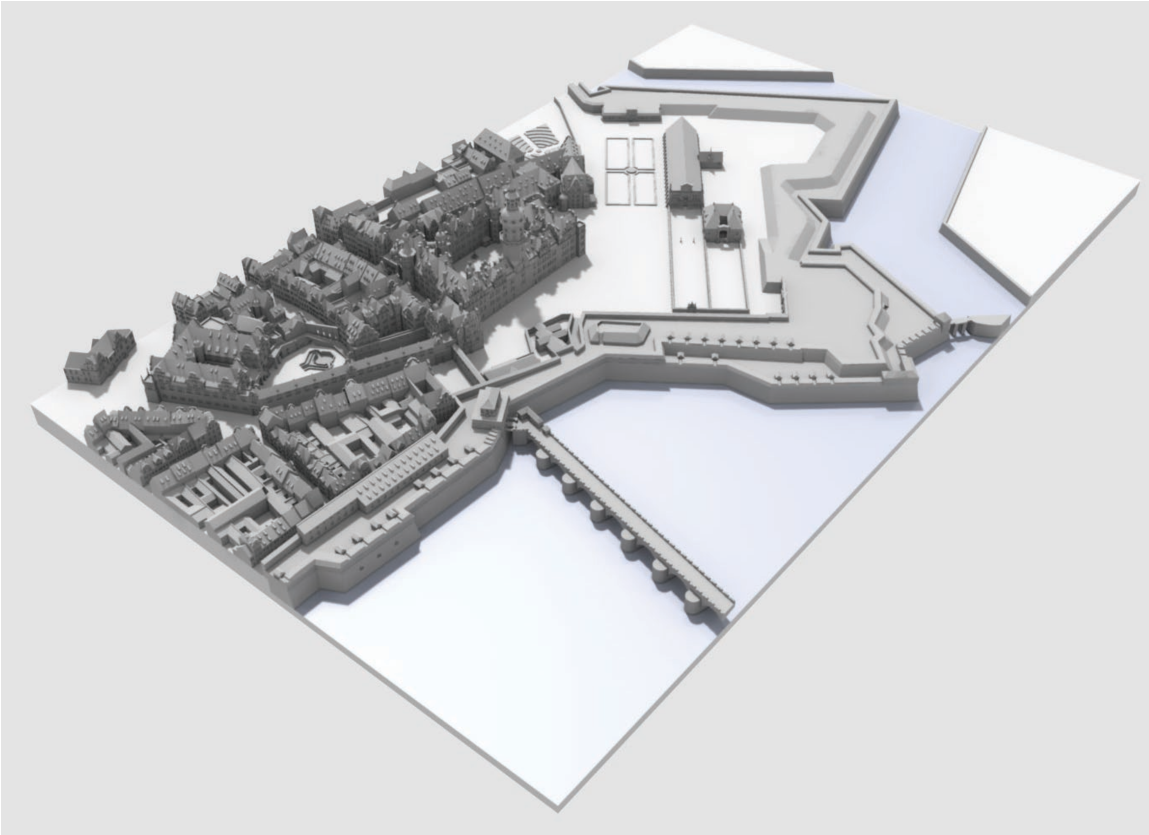

Fig. 37 Virtual city model of the Dresden castle and its spatial surroundings in 1678, rendering 2011.

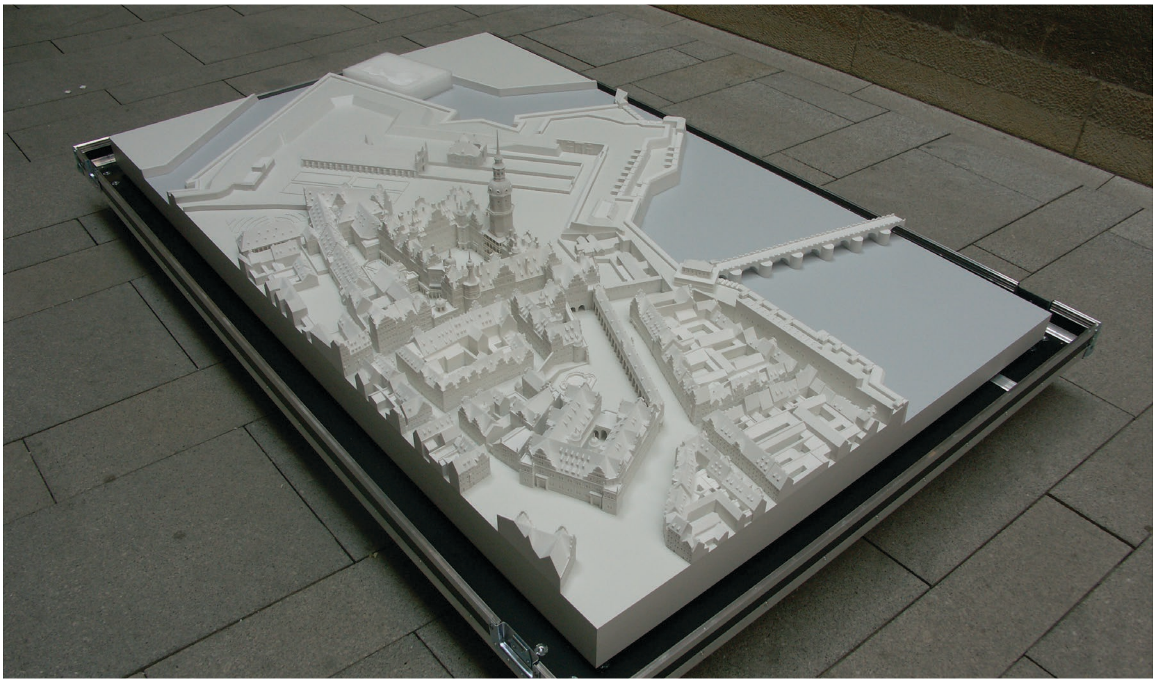

Fig. 38 Haptic city model of the Dresden castle and its spatial surroundings in 1678, 2011.

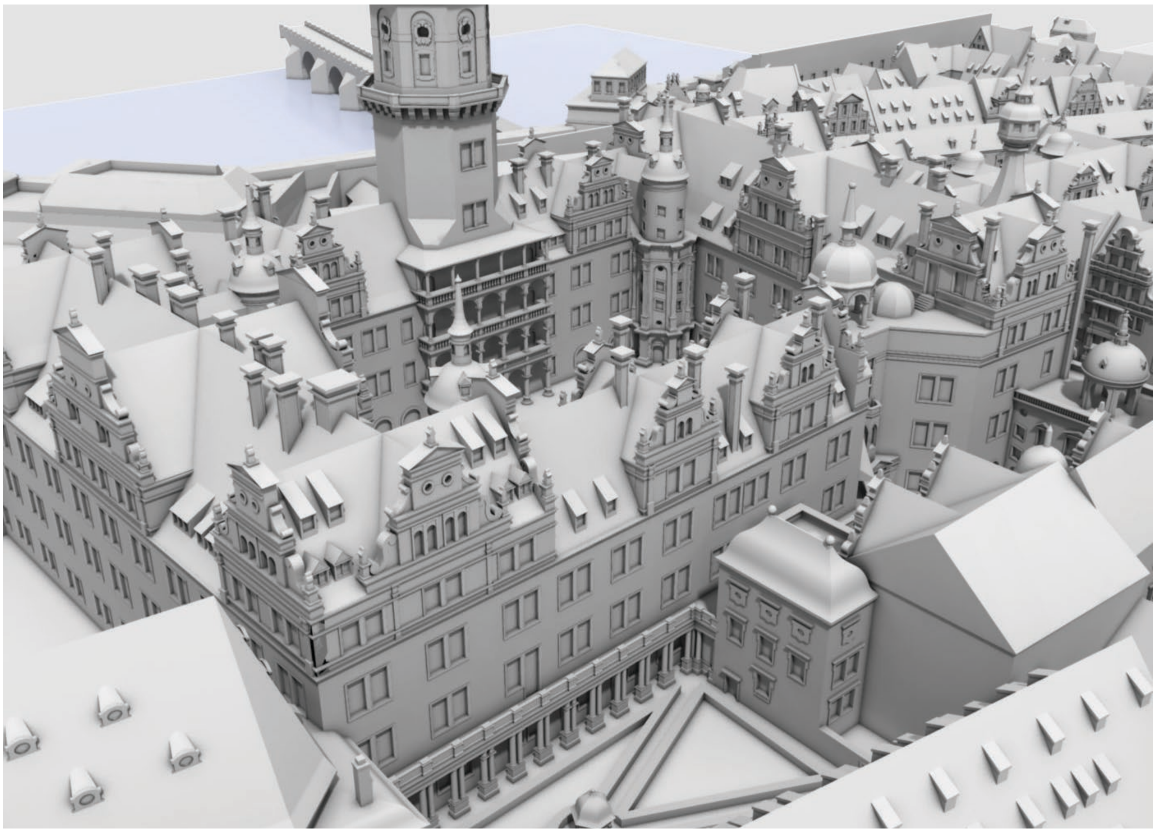

Fig. 39 Detail of the virtual model, rendering 2011.

Fig. 40 Detail of the haptic model, 2011.

Within the context of exhibits, aesthetic reasons could also lead to traditional kinds of haptic models. But in a scientific context the rapid prototyping technology offers immense opportunities. For example, a computer check of the model in every stage and the possibility to easily update the model. This is particularly useful for city models. And should there be changes due to results from research, individual areas can first be virtually newly constructed and checked and then reproduced in the plaster printing procedure. Such procedures give new possibilities for reconstructions in haptic models in the context of scientifically based speculations. And it allows to fill gaps or to exchange things in these models easily when new knowledge is available. In the Dresden model for example the buildings are grouped together in blocks about 30 × 20 cm and just plugged on the board. The main buildings are separate. If there is new scientific knowledge, the virtual model could be changed and after this the new building(s) will be printed and sent to Dresden for replacing.

Fig. 41 Exhibit 'Medieval Cities', 2006.

Fig. 42 Rapid prototyping city model, 2006.

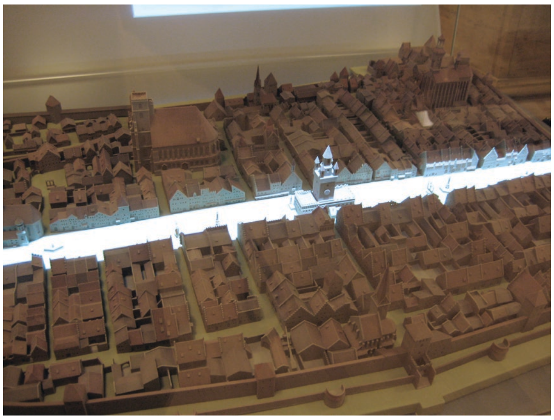

Fig. 43 Illuminated market street, 2006.

Fig. 44 Market street in the virtual model, 2006.

The further development of this approach led to so-called 'hybrid exhibits'. Here the advantages of digital and haptic models can be shown in one exhibit. An example is the exhibit about medieval cities in the Deutsches Historisches Museum, Berlin (fig. 41). The exhibit consists of two parts: a reclining haptic city model (fig. 42) and a vertical projection screen behind the model. Both are vehicles of information. The contents correspond with each other. For example, if individual functions and utilizations of the medieval city are picked out as the central theme on the projection screen, the respective buildings are illuminated on the model. Furthermore, the buildings and city areas located on the haptic model can be observed from a pedestrian's perspective as virtual models on the projection screen (figs. 43-44). This led to new possibilities for using haptic models.

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Illustrations

Fig. 1, 3, 6-7, 11, 15-16, 19, 23-25, 27-40 Technical University Darmstadt, Department Information and Communication Technologies in Architecture (fig. 19: also Franziska Haas).

Fig. 2, 4, 5, 8-10, 12-13, 14 (top left, top right, middle left, bottom left), 20-21, 41-44 Architectura Virtualis GmbH, Darmstadt.

Fig. 14 (middle right) Stuttgarter Bilderspalter, 820-830 AD, Landesbibliothek Stuttgart.

Fig. 14 (bottom right) Thomas Pusch, Creative Commons.

Fig. 17 Syndram and Starke 2001, fig. p. 36.

Fig. 18 Weck, Anton, *Der Chur-Fürstlichen Sächsischen weitberuffenen Residentz und HauptVestung Dresden Beschreib- und Vorstellung*, Nuremberg 1680, reprint on CD by Dresden Buch 2009.

Fig. 22 Syndram and Starke 2001, fig. p. 27.

Fig. 26 Mock, Johann Samuel, *Verleihung des Hosenbandordens an Kurfürst Johann Georg IV. im Dresdner Schloß 1693*, in Dülberg et al. 2009, fig. p. 53.

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1 The title and the following text uses the terms 'uncertainty', 'sharpness' and 'complete models' which refer to the inviting text of the workshop. See http://www.kunstwissenschaften.uni-muenchen.de/forschung/symposien/archiv/symposien2012/virtual_palaces/index.html (last accessed on 27.07.2015)

2 Virtual reconstructions of the Technische Universität Darmstadt, Department Information and Communication Technologies in Architecture, http://www.ika.tu-darmstadt.de/ and Architectura Virtualis GmbH, cooperation partner of Technische Universität Darmstadt. http://architectura-virtualis.de/

3 See also Grellert 2007.

4 See also Grellert and Svenshon 2010.

5 A proposal for such a documentation was made by Mieke Pfarr-Harfst. Pfarr 2010.

6 Deppe 2006.

7 Stanislaw-Kemenah 2006.

8 Papke 1997; Dülberg et al. 2009; Syndram and Starke 2001; Dresden 1989.

9 We received support from numerous institutions and individuals, such as: Staatliche Kunstsammlungen Dresden, Hauptstaatsarchiv Dresden, Landesamt für Denkmalpflege Dresden, Staatliches Bau- und Immobilienmanagement Dresden. Comprehensive Information one finds in the credits of the film.

10 In an article of 2009 Tristan Weddigen for example had already pointed out the modified geometries and subjectively adapted surface treatments in the cityscapes of the 18th century by Bernardo Bellotto, called Canaletto. Weddigen 2008.

11 The models were edit by the chair of Informations- und Kommunikationstechnik in der Architektur, TU Darmstadt und Architectura Virtualis GmbH under the scientific direction of Professor Manfred Koob.

12 Grellert and Svenshon 2010.

13 Magirius 2009.

14 The reconstruction of the late Gothic twined rib vault was performed by Anwand Architekten, KUS Tragwerksplanung, SIB Dresden. Scientific advisors were amongst others Stefan Bürger, Heinrich Magirius and David Wendland.

15 Cf. Magirius 2009, p. 28.

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18 We thank the Saxon Archaeological Heritage Service and State Museum for Prehistory, in particular Jens Beutmann and Susann Schöne for the provision of the excavation results.

A Review of Sources for Visualising the Royal Palace of Angkor, Cambodia, in the 13th Century

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The World Heritage site of Angkor in Cambodia which flourished between the 9th and 15th centuries is famed for its many beautiful stone temples including the renowned complex of Angkor Wat. But the stone structures we see today are only the 'religious skeleton' of what was once and thriving Southeast Asian metropolis.[1] Fluctuations of a tropical climate have largely erased the many thousands of wooden residences that made up the living city of Angkor. First among the perished wooden buildings of Angkor was the Royal Palace within the walled urban enclosure of Angkor Thom. To reconstruct a digital model of the Royal Palace that corresponds to an authentic vision of 13th-century Cambodia and takes into account uncertainty in our current state of knowledge, studies must first consult the considerable literature of history, architecture, cartography, and archaeology of the site of Angkor. Existing visualisations have had limited success in communicating a realistic Angkor, disadvantaged by partial consultation to current research. A survey of known studies of the Palace and its surrounds will pave the way for a richer and nuanced view of the Angkorian world.

Construction of the Royal Palace begun in the early 11th century and was inhabited by the Angkorian elite until the mid-15th century. The Palace was undoubtedly one of the largest wooden buildings at Angkor. Nothing of the Palace superstructure remains today, but tantalizing eyewitness accounts from a 13th-century Chinese emissary to Angkor describe a series of commanding buildings covered with lead tiled roofs linked by long corridors and complex walkways. Scholars of Angkorian history have speculated upon the appearance of the Palace in text, but none have attempted to generate visual representations of its form. To date television documentaries and magazine illustrations have reproduced the Angkorian Palace with inconsistent results. What is required is an approach that unites up-to-date scholarly knowledge and virtual modelling accommodating of alternative possibilities.

Imagining the Royal Palace in the 13th Century

Angkor Thom (in Khmer, 'Great City'), is a walled and moated square enclosure covering an area of 9 km^2. Likely established in the 12th century by king Jayavarman VII, it embraces an urban complex of house-mounds, ponds, canals and streets including several monuments from earlier eras. At the centre of the enclosure is late-12th-century Bayon temple, notable for its 'face-towers'. The site of the Royal Palace lies in the northwest quadrant of Angkor Thom. The Palace complex underwent numerous modifications over its life-span, the most significant during the beginning of the 13th century under the reign of Jayavarman VII.[2] Arguably, the most valuable description of the Palace is that of Chinese emissary Zhou Daguan who visited Angkor for eleven months from August 1296. Although Zhou did not enter the residences he describes his admission inside the Palace walls and audience halls:

> 'The royal palace, officials' residences, and great houses all face east. The palace… is about five or six li in circumference. The tiles of the main building are made of lead; all the other tiles are made of yellow clay. The beams and pillars are huge, and are all carved and painted with images of the Buddha. The rooms are really quite grand looking, and the long corridors and complicated walkways, the soaring structures that rise and fall, all give a considerable sense of size.
>
> In the place for doing official business there is a gold window, with rectangular pillars to the left and right of the crosspieces… I have heard that there are many wonderful places in the inner palace, but it is very strictly out of bounds and I could not get to see them.'[3]

French Archaeologist Bernard-Philippe Groslier who conducted excavations at the Palace in the 1950s and 60s provides another useful description:

> '…in former days Angkor was a sea of roofs. In the centre of the city sparkled the green and gold tiles of the royal palace, rising above its plain surrounding wall of red laterite. The general plan of the palace buildings resembles that of the flat temples: a series of main buildings intersecting at right angles and marking off various courtyards and quarters according to their respective functions – reception rooms, private apartments, gynaeceum and offices. The state rooms must have been magnificent: steep roofs carved and gilded arched roof-trees, and walls of precious woods…the audience hall…was supported by pillars resting on consoles…At the end of the hall was the elevated window where the king sat…This was the only part of the building open to the public.'[4]

Written descriptions evoke compelling images but are problematic for developing virtual models that must consider a myriad of additional material. Creating a virtual model of the palace is more challenging when many details of the Angkorian world are the foci of ongoing scholarly debates.

For example, while researchers generally agree that many aspects of the architecture of stone temples were modelled on existing wooden structures, there is question to the character of these 'temporary' buildings and ornamentations.[5] Modellers must be cautious as the interplay between stone and wood is unknown. To achieve 'authenticity' one approach is to situate the visualisation amidst its historical environs. In this example, a visualisation of the Palace can incorporate models of the monuments that adjoin it already re-imagined in illustrations,[6] 3D models[7] and real-world conservation surveys.[8]

Fig. 1 A photo of a double page spread in the 1960 National Geographic Magazine showing the New Year's festival at Angkor by Maurice Fiévet as described by Zhou Daguan.

Historical events and daily life at the Royal Palace have been represented in magazine illustrations and in television documentaries. With notable exceptions[9] these have not been bound to concerns of historical accuracy.

In the 1950s, the French artist Maurice Fiévet collaborated with the archaeologist Bernard-Philippe Groslier and historian George Cœdès to create a series of dramatic paintings depicting life in ancient Cambodia. These paintings appeared in the National Geographic article *Angkor, Jewel of the Jungle*.[10] Though Fiévet's images do not explicitly show the structure of the Palace several scenes are within or very close to it. The king and queen are seated on what is presumably the sandstone monument known as The Terrace of the Elephants, with the Palace behind them (fig. 1).

In another image, Palace attendants are dressed in vivid textiles and gold adornments inside a high roofed room. There is another depiction of the interior of the Palace where the king holds court in an audience hall. In this case, the partnership of artist and scholar produced visualisations with compelling authenticity.

The Channel 4 series *Lost Worlds: City of God Kings*[11] produced a CGI (computer-generated imagery) visualisation of the centre of Angkor Thom including a representation of the Royal Palace (fig. 2). This visualisation of the Palace was the first published digital modelling of the Angkorian royal enclosure. The digital model acknowledges the account of Zhou Daguan by showing lead roof tiles and partially gilded wooden structures. In one scene the king appears before an assembled crowd of costumed Angkorian officials and Chinese dignitaries. In contrast to Zhou's account the king emerges from a gold window open to an external courtyard rather than from within an audience hall.

Fig. 2 A still frame from the 2002 documentary *Lost Worlds: City of God Kings* showing the Royal Palace.

In 2011, the Korean Educational Broadcasting System (EBS) production *The Land of the Gods: Angkor*[12] generated a detailed visualisation of the Palace by lavishing considerable visual effects on decorative elements such as roof tiles, pavilions and gold statuary. Residential structures and wooden buildings were completely absent, and the impression presented was that the layout of the Palace was identical to a temple complex but without elevated levels.

Research at the Royal Palace

The Kings of Angkor habitually renovated their constructions. The Royal Palace had a complex life-span and numerous buildings were modified, altered and used for different purposes during its history. It is likely that each new sovereign placed their mark upon the Palace by remodelling structures and re-assigning the function of buildings. Conflict also likely changed the structure of the compound. During later periods (probably after the 15th century) there is evidence of the demolition of old structures and the re-employment of stone to fashion new buildings.[13] Although numerous buildings, stone walls and foundations remain, there is little robust archaeological evidence to suggest the function and operation of these structures. Nevertheless, one can envisage a series of buildings and constructions devised to service the Royal household and support the administration of the Empire.

Fig. 3 The Terrace of the Elephants and the main entry to the Royal Palace (photo, 2009).

Surrounded by a 5 metre high stone wall and a 25 metre wide moat the Royal Palace compound stretches 245 metres (north-south) and 585 metres (east-west) enclosing an area of almost 15 hectares. To the east, at the front of the Palace, there is a 300 metre long sandstone terrace, known as The Terrace of the Elephants, famed for its many representations of elephants along its walls (fig. 3). The terrace was probably once covered with a wooden pavilion which the king used as a viewing platform during events held in the adjoining 'Royal Square'.[14]

Fig. 4 The large pond – Srah Sré – on the north side of the Palace (photo, 2009).

The moat can be crossed at five points through large sandstone entry gates (*gopuras*). Inside the compound are four ponds lined with stone steps. The largest pond measures 125 x 45 metres and dates between the 12th and 15th centuries (fig. 4). At the approximate centre of the Palace compound is a temple-pyramid of three levels known as Phimeanakas and considered the 'royal shrine' of the Khmer kings (fig. 5). It is likely this temple existed before the Palace compound as it is not aligned with the eastern entry gate.[15]

Fig. 5 The temple-pyramid known as Phimeanakas (photo, 2010).

The Baphuon temple, just south of the Royal Palace, was also an important part of the ritual life of the court. Like Wat Preah Keo (The Silver Pagoda), the royal pagoda in Phnom Penh the Baphuon shrine likely serviced the specific needs of royalty.

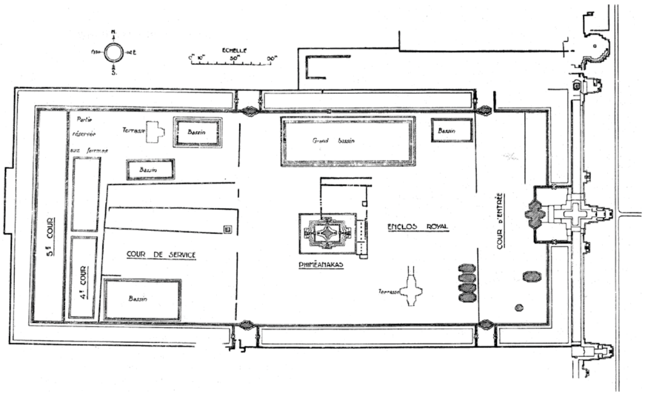

Fig. 6 Layout of the Royal Palace (Glaize 1993, p. 112 after Marchal 1926).

An early survey of the Royal Palace was conducted by French archaeologist Henri Marchal in the second decade of the 20th century.[16] Concluded from surface stone foundations Marchal's 'sketch-plan' divides the royal compound into five zones (fig. 6). Each subdivision was assigned to a specific activity of palace life including the dwellings of the king, his entourage, and various services.[17] For Marchal, the discovery of many ceramics and sandstone mortar and pestles in the third 'court' suggest the preparation of food, cosmetic make-ups and medicines in this particular area.[18]

Reconstructing the Palace

In addition to the extant structural remains a satisfactory virtual model of the Palace can draw from numerous sources including depictions of wooden architecture carved in relief on temple walls, modern and contemporary wooden architecture, and possibly the Indian prescriptive architectural treatises said to influence the architectural structures in Cambodia.

Fig. 7 3D modelling tests (2008) of wooden building components shown in the reliefs. On the left, cloth curtains hang between the pillars, and on the right, the structural framework beneath the tiles.

The bas-reliefs of the Angkor Wat, Banteay Chhmar and Bayon temples possess numerous representations of wooden architecture. A relief panel on the southern outer gallery of the Bayon, in particular, has been identified as depicting the Royal Palace (fig. 8).[19] Dumarçay[20] observes that most of the buildings depicted are open pavilions with removable hangings to demarcate space (e.g. fig. 7). When walls are shown, windows are installed with lathe-turned balusters and cloth curtains. Roofs rest on pillars, the doors are large and carved, and there are representations of large barracks, kitchens and storehouses.

Fig. 8 A bas-relief from the southern outer gallery of the Bayon depicting the Royal Palace (photo, 2009).

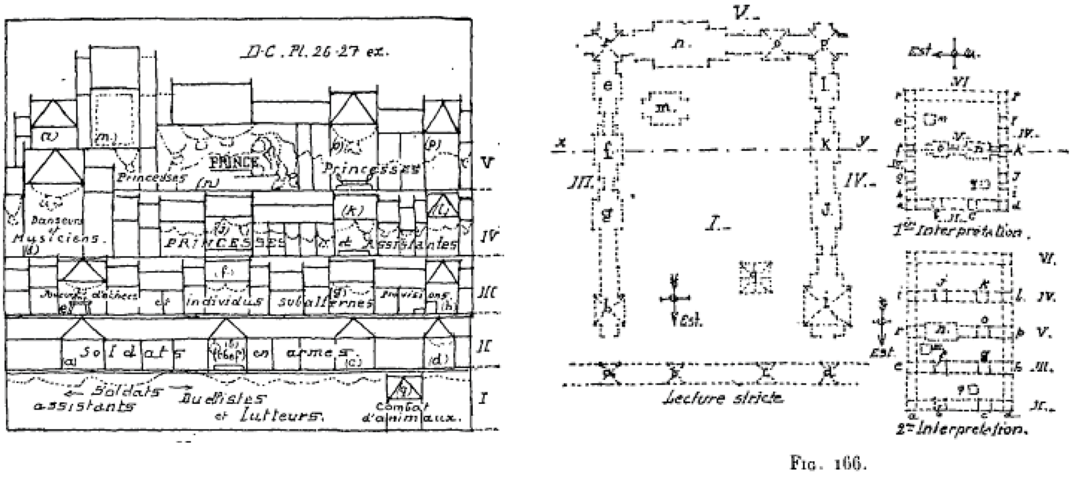

Fig. 9 On the left, a schematic drawn up by George Groslier from the bas-relief in fig. 8 above;
on the right, three possible interpretations of the layout of buildings depicted in the bas-relief (both 1921).

George Groslier[21] offers three interpretations of the Bayon bas-reliefs (figs. 8, 9). The first is a strict reading of the representation which hypothesises that the sculptors have depicted the four sides of the building by placing them one above the other and the galleries form a quadrilateral. Another interpretation considers that the artists did not depict another gallery that closed off the square. When the viewer enters from the east they encounter courtiers playing chess and chatting. This gallery is closed off on the north by a store-room, princely apartments, and another gallery sheltering a group of adorned and decorated female Palace attendants. A possible representation of the Palace garrison is illustrated by a group of armed soldiers grouped around their leader. Following Groslier's spatial logic these are situated north of the main residential area in the same relative position that barracks are sited at the contemporary Royal Palaces of Cambodian and Thai royalty in Phnom Penh and Bangkok respectively. Groslier's final interpretation suggests an adherence to social rank and hierarchy by representing the pre-eminence of the Prince or King in the relief. When laid out as a plan view, visitors must cross the gallery of guards, a courtyard, a gallery of Palace personnel, another courtyard, and the Palace harem before meeting the Prince or King. This plan apparently resembles the layout of large temple complexes, notably the late-12th-century Banteay Chhmar in Banteay Meanchey province, where to reach the sanctuary one must cross eight galleries and seven courtyards.

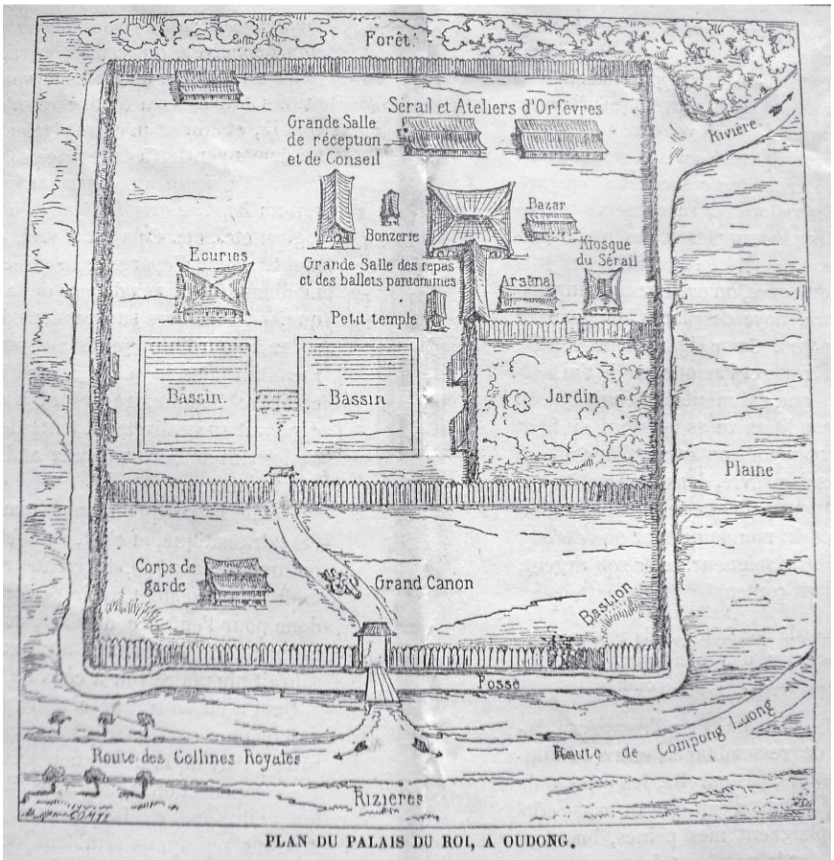

Fig. 10 A plan of the Palace at Oudong published in the magazine *L'Illustration*, 1864.
Note the enclosed garden at the centre-right of the palace compound.

The bas-reliefs do not depict the entirety of the Palace compound and alternative sources of comparison must be sought. Sometime after the late 14th century the Kings of Cambodia moved their administrative and ritual centres to southern Cambodia. Although scholars must be cautious to draw comparisons between different eras, representations of palace sites at Oudong[22] (fig. 10), Longvek[23] (fig. 11) and Phnom Penh[24] provide applicable reference points for the spatial layout of the Angkorian Royal enclosure.

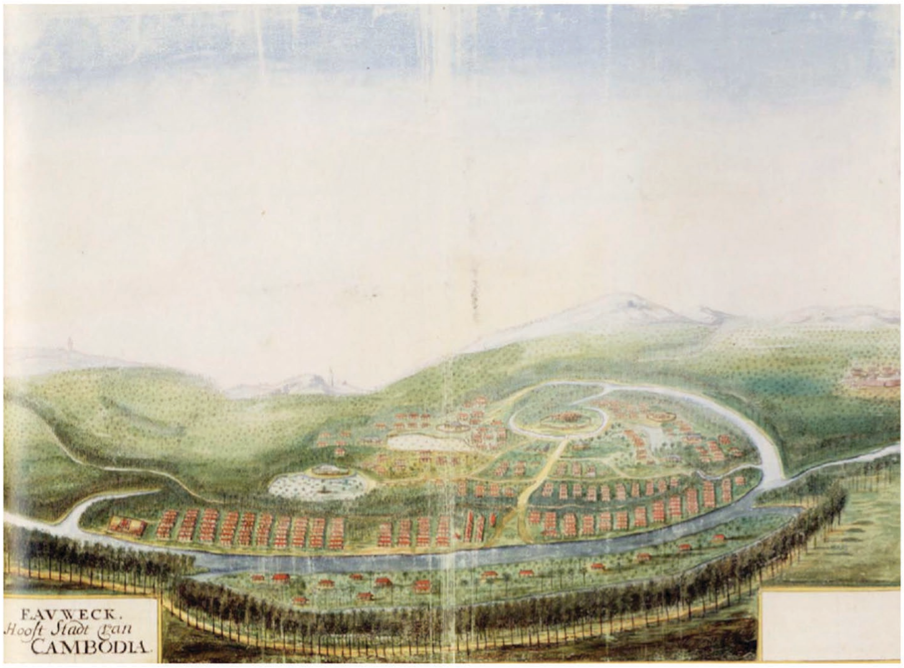

Fig. 11 A reproduction of a 17th-century Dutch map of the Cambodian capital Longvek (Johannes Vingboons, ca 1665).

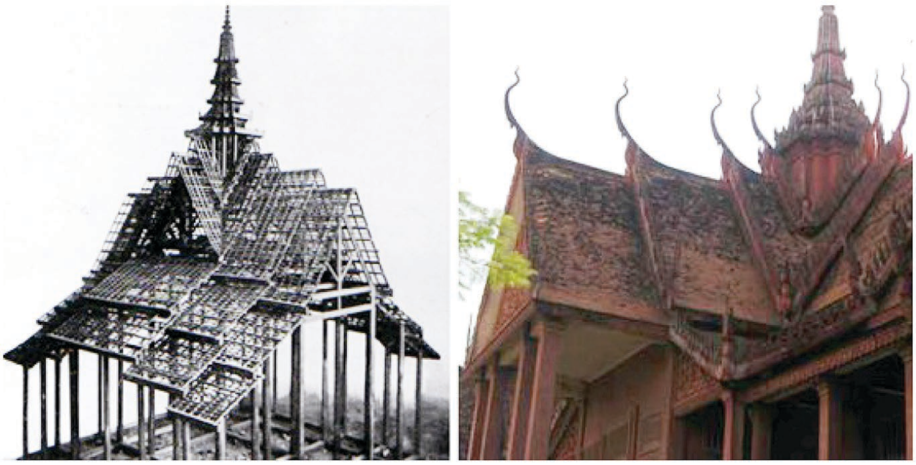

Fig. 12 Left: a photograph of a scale model detailing the internal roof structure of the School of Cambodian Art in Phnom Penh (1921).
Right: the roof over the main entrance to the National Museum of Cambodia (2008).

Another suitable reference for the wooden structures of the Royal Palace is the National Museum of Cambodia (fig. 12). Designed by the historian and curator George Groslier, and originally housing the l'École des Arts Cambodgiens de Phnom Penh, the National Museum of Cambodia was modelled on traditional Khmer architecture. The Museum inaugurated in 1920 includes a wide range of Khmer decorative elements. Local artisans from l'École des Arts Cambodgiens participated in its design and construction. George Groslier was integral in reviving traditional Cambodian arts and crafts. His considerable knowledge of Khmer architectural forms allowed him to elaborate the Angkorian palace prototypes from the bas-reliefs (see above) and reinterpret them with colonial eyes to fashion a building of requisite size.[25] This impressive building is worthy of a wooden Palace structure and of analogous size to what we might expect at the Royal Palace.

Based upon the prevalence of iconographic motifs and deities that took their origin in India and an attested knowledge of Sanskrit literature, scholars have often supposed that the metrical, proportional and compositional forms of medieval Khmer temples and urban enclosures were derived from Indian texts.[26] These texts may provide a reference point for the internal spatial layout of the Palace compound. Known generally as Śilpaśāstras (technical treatises) or Vastuśāstras (treatises on dwellings) the texts cover numerous subjects and art forms, from the layout of whole villages, to the pendants which must adorn the ears of individual images of the gods. The śāstras declare that an artwork or architectural structure (including urban plans) must adhere to specific aesthetic and spatial requirements to fulfil their proper spiritual obligations.

The temples of medieval Cambodia and the 'city' of Angkor Thom were constructed according to principles that aligned the structures to cardinal directions, emphasizing the importance of the centre, and observed rules of proportionality and symmetry. Yet reference to the application of Indian śāstras must be considered with caution. No direct correspondence between them and the Khmer monuments has been recognised. Additionally, there is no evidence within the Khmer epigraphic record that architects used such texts to create their buildings or towns. The medieval Khmer knowledge of Brahmanical literature was extensive, but there is no known mention of specific architectural treatises, or components of other works that contain passages on architecture and planning.[27]

Nevertheless, for the French archaeologist, Jacques Gaucher[28], Angkor Thom and the Royal Palace are the result of a Brahmanical conception of space on the one hand, and large scale Khmer adaptation to natural, topographical and hydraulic conditions on the other. Because the Angkor Thom design is apparently conceived without precedent, it must draw inspiration from an external urban model whose origin are the Indian śāstras. Gaucher points to the generalities of urban design discussed in treatises like the Arthaśāstra, Smarangāṅasūtradhāra, Mayamata, and Mānasāra.

Of possible correspondence were the proportional subdivision of the space into rectilinear and square components, and the location and proportionality of the 'Royal Palace' relative to the greater complex.[29] The Mayamata and the Mānasāra, contain numerous descriptions of villages, towns, temples, houses and palaces with declarations of proper orientation, dimensions, and materials. The Mayamata, in general, specifies plans for palaces that comprise three separate square enclosures with the innermost enclosure centred around a shrine dedicated to Brahma, situated next to the dwellings of the king and queen respectively; the whole group of buildings open to the east.[30] A possible correspondence is provided by Zhou Daguan who situates the Phimeanakas as being within the king's sleeping quarters when he says: 'About one li further north again there is the residence of the king. There is another gold tower in his sleeping quarters.'[31]

Recent archaeological investigations provide considerable information for reconstruction of the Palace. The application of innovative remote sensing technologies like LiDAR[32] allows archaeologists to see below the dense forest and ascertain the layout of urban settlements, hydraulic features and temple structures. Preliminary examination of the data clearly reveals the first enclosure originally proposed by Marchal[33], and shows elevated ground on all sides of the Phimeanakas shrine. Additional analysis of the Palace LiDAR has potential to reveal the composition of the original wooden structures of the compound.

As the centre of the capital, the Royal Palace was no-doubt a bustling administrative hub overseeing many aspects of Empire management. Among the duties of the administration was to commission and manufacture images of the gods to furnish the temples. The Khmer Kings invested great resources in sculpture making consistent with an image's ability to fulfil spiritual necessity and confer political legitimacy. One centre for manufacture of sandstone and bronze images was just outside the northern of the Royal Palace. The close proximity to the Palace suggests that these ateliers were of great importance to the kings of Angkor. Ongoing archaeological excavations[34] at this site reveal the activities that surrounded the Palace during the 13th century and can provide a perspective point from which to situate an eye-level view of the compound as it might have been viewed from outside the walls.

The Palace in Context: Vegetation, Houses and Inhabitants

Visualisations of Angkor produced by the author have thus far focused on subsidiary architecture, urban agriculture and most importantly moving figures.[35] In contrast to the architectural focus of many previous 3D visualisation studies at Angkor, these reconstructions consider the space between the monumental structures and the archaeological layout of the site. The monuments are indistinct because they are viewed from afar. By contrast, the vertical forms of shade and fruit trees clustered around urban settlement dominate the visual field of the image.

Based upon the information in his accounts, it is likely that Zhou Daguan spent much of his time at Angkor inside the walls of Angkor Thom. Zhou's descriptions of social differentiation among the residences and seems to describe a layout of buildings near the Palace and he talks of the 'great houses' facing east.[36] Dumarçay and Royère hypothesise that the dwellings in Angkor

Thom were not contiguous but consisted of houses detached from one another and surrounded by a small plot of land serving as a garden.[37] Both Gaucher's surveys of Angkor Thom[38] and the LiDAR data appear to substantiate this proposal. Using the Angkorian bas-reliefs and contemporary architecture Dumarçay and Royère[39] reconstitute the appearance of a house and residential quarter to populate the city. It is likely that Angkor Thom was indeed occupied by such wooden dwellings and was also complete with utilitarian vegetation (e.g. fig. 13).

Fig. 13 A virtual model depicting a section of Angkor Thom based on archaeological mapping, circa 1300 CE (2009).

An understandable preoccupation with the stone temples belies the probability that Angkor was fundamentally a 'green city' abundant with vegetation. Graham[40] notes the lingering prejudice among historians and archaeologists to regard social complexity and civilization and the absence of agriculture and vegetation. In this view tropical low density pre-industrial cities are problematic because they do not conform to recognizable patterns or urban development or demonstrate a dichotomy between green space and urbanization.[41]

In contemporary mainland Southeast Asia specific trees maintain religious and utilitarian associations with Buddhist pagodas.[42] For example, sugar palm leaves are used for temple manuscripts and the Bodhi tree *(Ficus religiosa)* is symbolically associated with the enlightenment of the Buddha. Palaeobotanical analysis conducted at Angkor supports the supposition that temple grounds probably contained large and deliberately planted stands and groves of trees.[43] Dumarçay[44] notes a 'very impressive tree' in the Palace grounds at Oudong in the 17th century and a walled garden is clearly evident in a 19th-century plan of the site (fig. 10). The Oudong walled garden accords with late-17th-century accounts of gardens at Ayutthaya[45] identified by

Branigan and Merrony[46] using a range of archaeological methodologies. In Java, Satari documents temple gardens as recorded in inscriptions and depicted on temple reliefs. These references distinguish specific plants cultivated near a hermitage and palace grounds.[47]

While domestic architecture, vegetation and trodden thoroughfares convey visions of an inhabited space, the inclusion of animated inhabitants brings the visualised city to life. Zhou Daguan's account includes numerous descriptions of the city's residents and provides considerable material to visualise the people of Angkor. For example, Zhou specifically observes the servant women of the Palace known as *chenjialan*:

> 'At the lower level there are also the so-called *chenjialan*, servant women who come and go providing services inside the palace and number at least a thousand or two. In their case they have husbands and live mixed in among the ordinary people. They shave back the hair on the top of their head….They paint the area with vermillion, which they also paint on to either side of their temples…They are the only women who can go into the Palace; no one else below them gets to go in. There is a continuous stream of them in on the roads in front of and behind the inner palace.'[48]

Though Figure 14 depicts an unspecified location at Angkor, its application of cultural and environmental specific aspects of 13th-century Angkor, such as ox-carts and sugar palms, produces a framework for which animated figures of the *chenjialan* might traverse outside the Palace compound.

Fig. 14 The virtual populace of Angkor: 3D animated models traverse a road beside a high laterite wall at an unspecified location at Angkor, circa 1300 CE (2009).

Alternative Approaches to Uncertainty

The material record recovered from archaeological sites represents only a fraction of the information needed to interpret and reconstruct the visual appearance of historical landscapes. Missing data therefore generates uncertainty about visions of the past.[49] The primary uncertainty of visualising the Royal Palace of Angkor is the precise character and layout of wooden structures of which it was composed. Notwithstanding considered historical and archaeological interpretations reconstructing a detailed view is a largely speculative undertaking. A complimentary approach is to visualise the Palace from the outside. Several key 'eye level' viewpoints from outside the compound could serve to communicate the size and scale of the Palace ensemble while avoiding specific decorative and structural details. During the 13th century the Palace was undoubtedly inaccessible to the common resident of Angkor Thom and adopting the perspective of these individuals provides an alternative authentic visualisation of the living city. Inhabitants of Angkor Thom walking along the roads near the Palace might glimpse commanding edifices with lead tiled roofs glinting in the tropical haze.

Privileged residents of Angkor Thom also likely viewed the Palace from elevated positions. Possibly obscured by trees, the Palace could have been seen from the summit of both the Bakheng and Baphuon temples. However, the most commanding view can be reconstituted from Zhou's account of the temporary New Year's festival structures:

> 'A large stage is set up in front of the royal Palace…it is hung everywhere with globe lanterns and flowers. Facing it on a bank more than two or three hundred feet away are some tall structures that are made of wood joined and bound together, like the scaffolding used to make a pagoda. They must be well over two hundred feet high. Every night they put up three or four of these…and set out fireworks and firecrackers on top of them… When night comes the king is invited to come and watch… the fireworks can all be seen a hundred li away…and make enough noise to shake the whole city…'[50]

Portrayed in Maurice Fiévet's painting (fig. 1) a complimentary virtual model could shift the viewpoint from behind the King's viewing platform to the heights of the scaffolding where the rockets are ignited. Moreover, a virtual reconstruction set in the evening with diminished lighting would obscure the details of the Palace compound which become indistinct and silhouetted thereby eluding the obligation for an uncertain detailed restitution.

Future Directions for the Palace

Given the limited definitive historical and archaeological evidence for the composition and function of the 13th-century Angkorian Royal Palace a single peremptory vision is not feasible. What is required is a plural approach that communicates alternative possibilities. Working from the bas-reliefs of the Bayon, a parallel approach was pioneered by George Groslier[51] who offered multiple interpretations to imagine the layout of the Palace compound. Within the scope of contemporary computer and multi-media interfaces it is unproblematic to offer plural visions of the Palace open to manipulation. In a visualisation that uses graphic scripting parts of buildings or entire edifices can be repositioned, realigned and rescaled according to art historical, archaeological or architectural evidence. Corresponding transformations can be applied to the positioning of trees and vegetation sets both inside and around the compound. An interactive visualisation (perhaps framed within a game engine) allows scholars and students to model the archaeological landscape directly.

Appraising the pending Palace of Angkor requires further research. Complimentary study of the layout and function of contemporary mainland Southeast Asian palaces, specifically those in Bangkok and Phnom Penh, may suggest possible correspondences. For example, there is a known correlation between the locations of the military garrison and artisanal studios relative to the ceremonial and administrative centre of the Kingdom. Additional research can also be made of historical palaces that have been too little studied. Identifying palaces at the urban predecessors to Angkor; the 7th-8th-century site of Sambor Prei Kuk,[52] and the 9th-century site of Mahendraparvata[53] (on the Kulen hills, bordering Angkor) could similarly assist in understanding the 13th-century Palace.

Arguably the most important historical source concerning Angkor and its Royal Palace are the first-hand observations of Chinese Emissary Zhou Daguan. Rather than a collection of sterile imposing structures, his vision of the city is one of a lived place; bustling with the activities of its population, its King and his court; replete with an ever changing landscape of rice fields and forest. Correspondingly, any endeavour to comprehend and visualise the glorious Angkorian past and its grand Palace must necessarily consider the context of its prosperity.

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[1] Cf. Groslier, B.-P. 1958, p. 108.

[2] Dumarçay and Smithies 1991, p. 41.

[3] Zhou (trans. Harris) 2007, p. 49.

[4] Groslier 1966, p. 163.

[5] Coral-Rémusat 1934, p. 246; Cunin 2004, 2007; Dumarçay, 1973; Dupont 1952, p. 40; Groslier, B.-P. 1960, p. 2; Marchal 1951, p. 10; Parmentier 1914, p. 246; Polkinghorne 2008.

[6] Delaporte 1880.

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[12] Kim Yu Yeol 2011.

[13] Marchal 1926, p. 305.

[14] Freeman and Jacques 1999, p. 155.

[15] Freeman and Jacques 1999, pp. 112-113.

[16] Marchal 1926; See also Aymonier 1904, pp. 121-122, 127-136, fig 17; Fournereau 1890.

[17] Marchal 1926, p. 316.

[18] Marchal 1926, p. 326.

[19] Dumarcay and Smithies 1991, pp. 42-44; Groslier, G. 1921, p. 303.

[20] Dumarcay and Smithies 1991, p. 44.

[21] Groslier, G. 1921, p. 303.

[22] Dumarcay and Smithies 1991, p. 45; Groslier, G. 1921, p. 334.

[23] Vingboons, c. 1665.

[24] Dumarçay and Smithies 1991; Jeldres 2003.

[25] Collins 2005; Peters 1994.

[26] Dagens, 1985a, 1985b, 1994; Gaucher, 2002, 2004a.

[27] Dagens and Barazer-Billaret, 2000, p. 269.

[28] Gaucher 2003, p. 242.

[29] Gaucher 2004b, p. 78.

[30] Dumarcay and Smithies 1991, p.5.

[31] Zhou (trans. Harris) 2007, pp. 47-48.

[32] LIDAR (Light Detection And Ranging) is an optical remote sensing technology that penetrates forest canopy with an approximate resolution 20 cm horizontally and vertically. The survey was coordinated by the Khmer Angkor LiDAR Consortium (KALC) in April 2012.

[33] Marchal 1926.

[34] The Ateliers of Angkor Project, an Australian Research Council Discovery Grant (DP110101968) coordinated by The University of Sydney. See Polkinghorne 2012.

[35] Chandler 2011; Chandler and Polkinghorne 2012.

[36] Zhou (trans. Harris) 2007, p. 49.

[37] Dumarçay and Royère 2001, p. 106.

[38] Gaucher, 2003, 2004b, KALC 2012.

[39] Dumarçay and Royère 2001, fig. 98, 104.

[40] Graham 1999, p. 191.

[41] Graham 2005; Evans et al 2007; Hawken 2011.

[42] Chandler and Polkinghorne 2012.

[43] Penny et al 2006; Penny et al 2007.

[44] Dumarçay and Smithies 1991, p. 45.

[45] de Chaumont and de Choisy 1998 (1685); de Choisy 1994 (1685-1686); Gervaise 1996 (1688); la Loubere 1693; Tachard 1688.

[46] Branigan and Merrony 1999, p. 19.

[47] Satari 2008.

[48] Zhou (trans. Harris) 2007, pp. 54-55.

[49] Zuk et al, p. 99.

[50] Zhou (trans. Harris) 2007, pp. 62-63.

[51] Groslier, G. 1921.

[52] Shimoda 2011.

[53] Chevance 2011.

Medieval Castles and their Landscape

A Case Study Towards Historic Reconstructions

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Scientific research concerning castles is most often centred on the object of the castle itself. Research concerns the history of the castle, its building phases, the structure of the 'castle' building or the archaeology of the main castle. The geographical context of the castle is often ignored. But to understand a castle not only as a building but as part of the social reality of its day it is necessary to put it back into its geographical context. That means to investigate the landscape surrounding the castle and to look at settlements, streets, rivers etc. and their position in the landscape in connection with the castle. That leads directly to another question the art historian has to deal with: A castle is a piece of architecture, it has real functions, but it is also built to impress people, to show power, and therefore the parts of the castle are designed in specific ways. And castles are often built and designed in a process of action and reaction – if my neighbour builds a castle at his border, I have got to build one as well, and mine will be seen from his castle, and therefore it must be impressive as well!

It is often impossible to understand these aspects in our modern landscape because too much has changed: there are woods surrounding the ruins of a castle, so that you cannot see it properly, the streets we use were made in the late 19th and the 20th centuries and the medieval streets are no longer in use. Most important is that the castle itself has seen many building phases during the medieval period which changed its appearance, and afterwards it became a ruin or sometimes it was even reconstructed in a romantic style in the 19th century. So, if we want to understand the way the castle presented itself to the passer-by during the medieval period we have to do a lot of reconstruction and we have to analyse the landscape surrounding the castle.

In former days, researchers had to wait until wintertime to be able to recognize at least some structures in the woods and to try to guess what could have been seen from a tower which no longer exists. Today, LiDAR-scans give us the opportunity to analyse landscape in a scientific way at any time of the year.

LiDAR-Scans are produced by scanning the ground of the earth from a plane, and by the kind of reflection and the time it takes you can create a three-dimensional model of the earth, without any trees or bushes – and without any buildings. With the help of these models, which may be as accurate as some decimetres, you can for example recognize old streets or paths which are no longer in use now, but which may have been the historical way leading to a castle. But LiDAR-scans give us yet another opportunity: with GIS-software it is possible to analyse exactly which areas you could have seen from a specific point, and it is even possible to raise the position of the viewer, so as if they were standing on the top of a tower.[1]

In addition, Computer Vision and Photogrammetry offer some more possibilities for the analysis of historic monuments. If there are any physical remains of a castle existing, it can be acquired as a three-dimensional model, only by taking a series of photos from particular directions. Basically everything one has to do is to take pictures of the object from all directions, but in the case of large-scale objects like a castle it is unfortunately mandatory to have some views from elevated positions, therefore it is necessary to have a bucket truck or an Unmanned Aerial Vehicle (UAV), usually a small multi-rotor drone.[2] Smaller objects, like capitals or other ornaments of the building require less effort, especially when they are reachable from all important sides. The resulting 3D model of the castle can be integrated in a LiDAR-scan if it contains geo-referenced control points, which leads to a scaled and oriented model for further processing in a GIS-software. However, any 3D acquisition method can only scan what is still there to be scanned today, which is in most cases dramatically different from the castle in the past. This is where synthetic 3D reconstruction comes into play, which attempts at creating scientifically valid 3D models of the castle and its landscape in mediaeval times, based on both the 3D scans and on educated guesses (expert knowledge). That is why LiDAR-scans, GIS-software, and 3D modelling software, are very important in the analysis of castles by the historians or the art historians, as the following three examples will demonstrate.[3]

The first example concerns the famous Castle Eltz in Rhineland-Palatinate, situated near the River Moselle, which was besieged in the years from 1331 up to 1337 (fig. 1). In this conflict, the so-called 'Eltzer Fehde', the nobles of the castles Eltz, Waldeck, Schöneck and Ehrenburg, all situated in the area in the west of Koblenz, acted against the Archbishop of Trier. We do not know the exact reason for the conflict but it seems to have been an act of defence of the nobles who tried to withstand Archbishop Balduin of Trier who tried to expand his power on both shores of the River Moselle.[4] Most probably the fighting started in summer 1331, and the nobles made their peace with the archbishop on 9 January 1336. Johann of Eltz only made his peace with Archbishop Balduin nearly two years later, on 16 December 1337.[5]

As a siege castle (called Trutz-Eltz or Balden-Eltz) is situated near Castle Eltz, the literature often says that Archbishop Balduin erected the siege castle in this conflict and that there he positioned a trebuchet which threw stones on Castle Eltz. As there was no archaeological or art historical research on Trutz-Eltz and a written source from 1453 tells us that the siege castle was ruined,[6] it is taken for granted that the building still looks the way it did when it was erected during the siege. Therefore authors always try to explain the way the siege castle looks just based on military aspects.[7] In two papers published in 2012 and 2013 Achim H. Schmidt, Koblenz, and Olaf Wagener could show that these 'facts' should probably be revised in some of the more important aspects.

Fig. 1 Castle Eltz seen from the North (2008).

All the findings and the former buildings and structures surrounding Castle Eltz were part of this analysis and the written sources were also taken into consideration, and analysed critically. The authors showed that there is another castle to the west of Castle Eltz, called 'Alte Burg'. Finally it became obvious that this castle must have been in use as a siege castle in the 1330s as well. The reason for this conclusion were the stone balls which were launched by the trebuchet – most of them were found in the western part of Castle Eltz – that is where you would expect them to be if the trebuchet stood in the 'Alte Burg' (figs. 2 and 3).

Fig. 2 'Alte Burg', main plateau (2008).

Fig. 3 Castle Eltz as seen from the 'Alte Burg' (2008).

It could also be shown that the siege castle Trutz-Eltz had been built in three stages, all of which date from the time of the siege. Maybe this was a position for a trebuchet as well, at least as long as the main tower had not yet been built, but that was obviously not the only purpose of that building.

Finally the written sources also show that the siege took part in different stages. The so-called 'Gesta Trevirorum' written only a short time after the events tell us for the year 1331:

> 'Contra quos [i.e. the nobles of Eltz, Waldeck, Schöneck and Ehrenburg] dominus Baldewinus exercituali potentia acies direxit, Eltz circumdedit, et Baldeneltz a fundamento constructum, quo ejus potentiam nihilavit, mirabiliter firmavit.'[8]

This passage can be interpreted as saying that Archbishop Balduin in a first step surrounded Castle Eltz (circumdedit) and that he only afterwards started to build the siege castle Trutz-Eltz. These theories can now be checked on their plausibility with the help of LiDAR-scans. For this purpose a short description of the terrain and the buildings will be given, so that the reader can easily understand the scans.

Castle Eltz is situated in the Eifel in the narrow valley of the River Elz [sic!] which winds its way to the River Moselle in the south. The castle has been erected on a small rock surrounded by the river on three sides. It is the last part of a ridge which stretches from northeast to southwest in the Elz valley. The surrounding ridges are nearly one hundred metres higher than the castle and they have a distance of approximately 200 metres to the castle. The castle was probably built in the 12 century[9] and in those days it was rather safe on its rock as neither the counterweight trebuchet nor firearms had been introduced in central Europe. But after the introduction of the counterweight trebuchet in the German speaking areas at the beginning of the 13th century it was possible to launch stone balls weighing more than 50 kg to distances of several hundred metres.[10] In consequence the place where Castle Eltz was erected had become vulnerable.

At the moment it is impossible to try to reconstruct what Castle Eltz looked like in the time of the siege in the early 14th century because there has been no archaeological or art historical research campaign until now and the castle is still in use and has seen many construction programmes since the Middle Ages.[11] The tower 'Platt-Eltz' in the northwest of the castle is definitely older than the siege and some parts of the outer defences in the north and west must also be older. Because of the structure of the rock it is very probable that the castle has always used the whole rock although its present state with the big neighbouring towers creates a misleading image of the castle in the 1330s. There are no signs of damage to be found in the castle which could have been caused by the siege.

The most impressive relic of the siege is the ruin of Trutz-Eltz. It is situated on the same ridge as Castle Eltz but is 220 metres distant and about 40 metres higher. So the castle whose terrain comprises about 1300 m², has the classical location of a siege castle (figs. 4 and 5). It mainly consists of a donjon built of slate, 11 × 11 metres square and 11.5 metres high, and a wall, a so-called 'Schildmauer' or chemise which leads from the donjon to the west. In the south is a small yard and in the north an outer ward or 'Zwinger'.[12]

Fig. 4 Castle Eltz on the left, Trutz-Eltz on the right (2008).

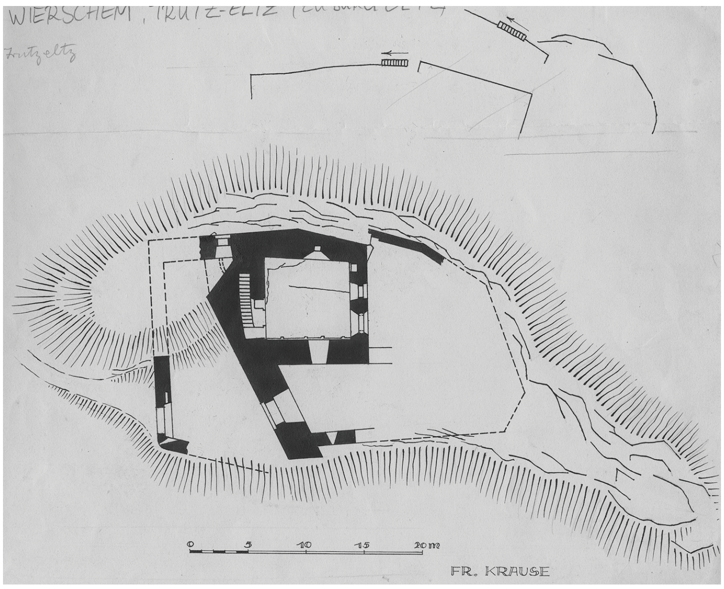

Fig. 5 Plan of castle Trutz-Eltz as drawn in the 1930s – until now it has always been published without the upper parts of the plan showing stairs and terraces in the slope.

Trutz-Eltz probably developed in three stages out of a simple fortification. Because of substructures in the west, especially the southern part of the fortification had a plateau big enough to place a trebuchet on it in the first phase.[13] The development of the castle took place in several steps, including changing plans. In the last stage the fortification was totally restructured. Maybe the reason was that it was no longer intended to have a mere siege castle (which normally would be destroyed after the siege[14]) but to build a 'real' castle in anticipation of a political solution. The written sources suggest that the building process stopped after the end of the siege, and art historical research did not show any parts which could be younger than the 14th century (figs. 6 and 7).

Fig. 6 Trutz-Eltz seen from the west (2008).

Fig. 7 Trutz-Eltz seen from Castle Eltz (2008).

Another fortification can be found to the west of Castle Eltz on a rock in a loop of River Elz. This fortification is called 'Alte Burg' (i.e. old castle) and was regarded as pre-medieval. It is situated in about 330 metres distance from Castle Eltz and at the same height; a ridge which descends between both castles from southwest is lower so that it is possible to look from each castle to the other directly (fig. 8).

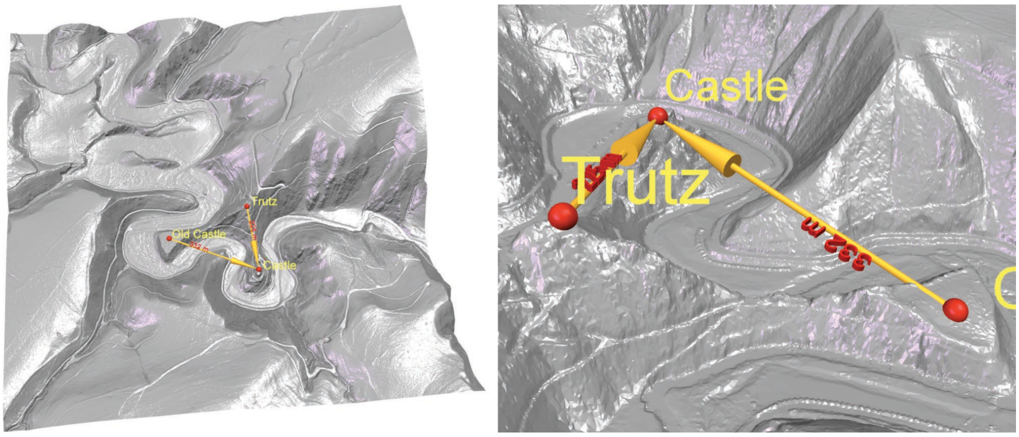

Fig. 8 Castle Eltz, GML-Rendering of LiDAR-scan of the surrounding landscapes and distances to Trutz Eltz (225 m) and 'Alte Burg' (332 m), (2010).

The ridge where the 'Alte Burg' is situated lies to the southeast and is part of the ridge where Trutz-Eltz can be found, too. It is an ideal place for a fortification: on three sides it is surrounded by the River Elz and the slopes are mostly nearly vertical. It can only be entered from the northeast, the saddle of the ridge. The plateau is of an almost triangular form and has an area of 0.49 ha. The narrow ridge in the northeast has been changed artificially in two places, and at least the inner moat has been built for the castle.

Directly behind the moat in the northeast is the highest part of the castle, a rock that has been artificially levelled. The levelling led to a triangular plateau of 25 × 10 metres. To the west is a flat step to the rest of the castle´s plateau. The southern edge of the big plateau in the south is a rocky ridge about one metre high. The plateau, slightly descending to the north is exceptionally even. The edges in the north and west seem to be the remains of an earthwork. In only two parts of the 'Alte Burg' there are remains of stone walls.

The overall impression of the 'Alte Burg' can be summarized as follows: The terrain which according to the findings was in use as a fortification or fortified settlement in prehistoric times could have been in use by the besiegers of Castle Eltz because of its favourable position. The stone wall on the western side seems to date from the Middle Ages because of its construction. It is not clear in which phase the big plateau was created but the space would be enough for the soldiers and equipment necessary in a siege. The terrain was very well protected and the second siege castle, Trutz-Eltz, provided additional protection (fig. 7).

Fig. 9 Stone balls in Castle Eltz, maybe thrown from the 'Alte Burg' (2008).

At this point two main questions arise:

- Why would Archbishop Balduin build not only one, but two siege castles? Why did he spend more time and more money?
- Why could the besiegers build a big tower or a small castle out of stone (i.e. Trutz-Eltz)? To erect stone walls takes a lot of time – why didn´t the besieged stop them?

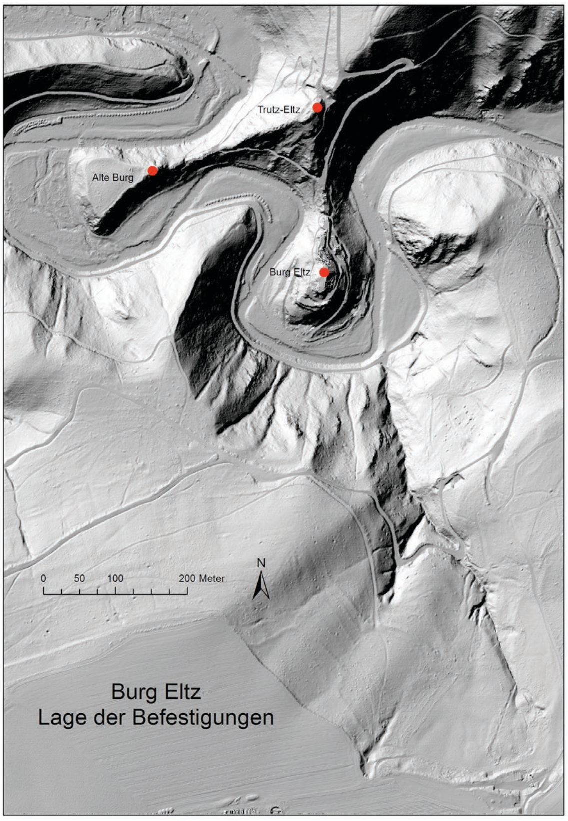

Fig. 10 Castle Eltz, LiDAR-scan of the surrounding area (2010).

Maybe it is possible to find an answer to these questions if we try to analyse the LiDAR-scans in direct comparison with the written sources. If we consider the place where Castle Eltz was built, a small rock in the middle of a deep valley, it is not surprising that even from a tower thirty meters high placed in the castle you cannot see too much of the surrounding terrain. Even the northern flank of the ridge where Trutz-Eltz and the 'Alte Burg' are situated cannot be seen (figs. 10 and 11).

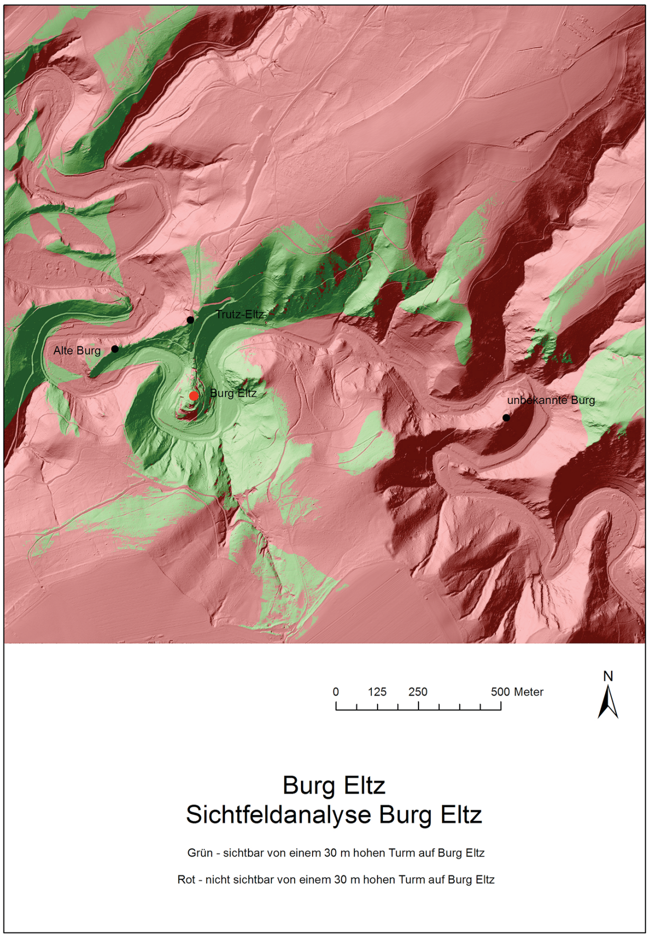

Fig. 11 Castle Eltz, LiDAR-scan, green are the areas that can be seen from a tower of 30 m height in Castle Eltz (2010).

If we now take a look at what could be seen from the place of the 'Alte Burg', we do not reconstruct any tower because there are no hints of the existence of one but we create the space which could be seen by a person, i.e. from two metres height. Not much terrain can be overviewed from there but at least the main entrance of Castle Eltz in the north and the building place of Trutz-Eltz are both visible (fig. 12). From the place where Trutz-Eltz has been built we can also see only a small portion of the surrounding country. But at least Castle Eltz and the 'Alte Burg' can be seen and the valley of the River Elz is visible both in the west and the east of Castle Eltz. The rising ridge in the northeast of Trutz-Eltz can only be viewed in parts (figs. 13 and 14).

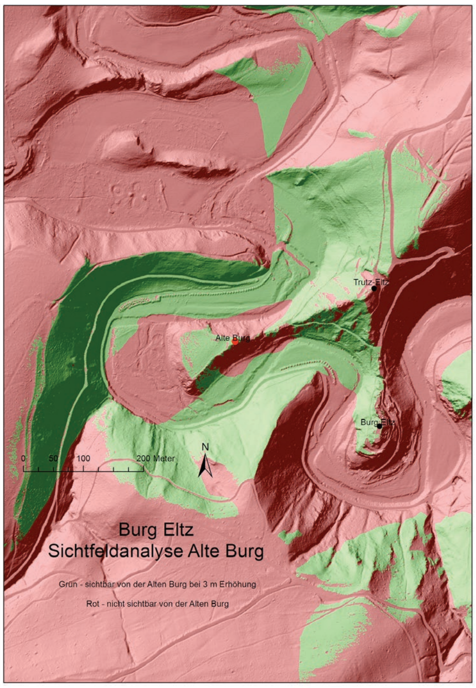

Fig. 12 Castle Eltz, LiDAR-scan, green are the areas that can be seen from a person standing on the 'Alte Burg' (2010).

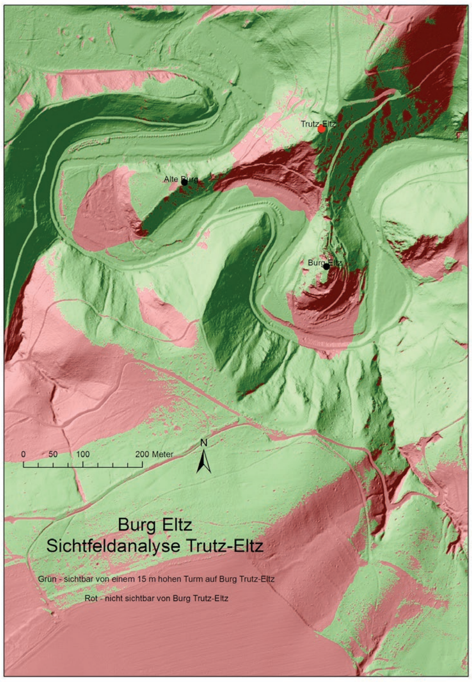

Fig. 13 Castle Eltz, LiDAR-scan, green are the areas that can be seen from a tower of 15 m height on Castle Trutz-Eltz (2010).

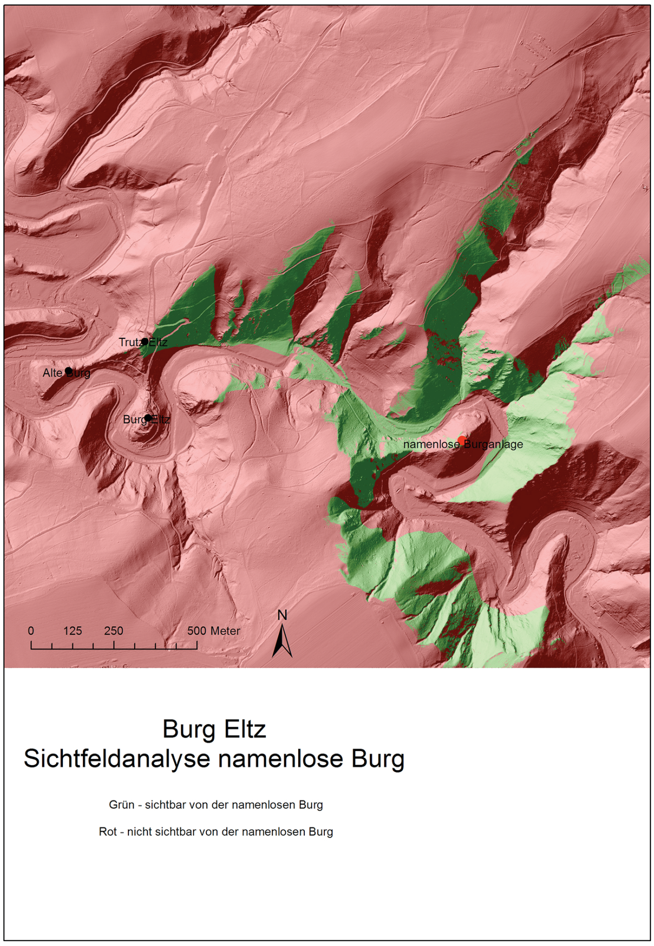

Fig. 14 Castle Eltz, LiDAR-scan, green are the areas that can be seen from a person standing on the nameless castle (2010).

If we now combine the two viewpoint-analyses we can reconstruct what it meant if both the 'Alte Burg' and the place where Trutz-Eltz in a later stage of the siege was built were in the hands of the besiegers: It is clearly visible that the written sources are confirmed because in this case Castle Eltz is surrounded – it is no longer possible to get into the castle without taking the risk to be seen by the besiegers. That does definitely not mean that Castle Eltz was totally blocked off from the outer world because then it would not have been possible to hold out for six years. But it shows that everybody who wanted to enter the castle had to take a risk, a risk they would have been aware of, because they would have seen the fortifications of the besiegers while nearing the castle and known they would have been equally visible.

These facts might be part of the answer to the second question: if the besieged had tried to attack the building site of Trutz-Eltz they would have been caught between the two fortifications of the Archbishop of Trier. They would not have been sure if there was a way back into the castle.

If we now combine these theories with the fact that Trutz-Eltz is a very outstanding siege castle because it comprises a complete donjon, it becomes clear that the whole affair was magnificently planned by Archbishop Balduin: without doubt the tower of Trutz-Eltz was a symbol which showed the besieged that the archbishop had invested (and could afford) much money in this siege. He would not withdraw before he had achieved his aims. But it is even more important that this symbol did not only function in regard of the people in the besieged castle but also in regard of everybody who wanted to reach the castle. It does not matter if you come from the heights in the northeast or through the valley of River Elz from north or west – the first thing you see is not Castle Eltz itself but the tower of Trutz-Eltz.

This case shows how LiDAR-scans can help us to interpret and understand written sources and questions concerning medieval castles. But that is only a first step. The second step would be to try to reconstruct what Trutz-Eltz could have looked like and to integrate such a virtual reconstruction into the LiDAR-scans. Then we could even show not only that the passer-by could see Trutz-Eltz but we could also present what the castle looked like from their point of view no matter which way they took to reach the castle.

This problem will be shown in a second example, Castle Stahlberg. Stahlberg is situated in the Middle Rhine Valley in Rhineland-Palatinate near Bacharach, some kilometres away from the Rhine itself. The castle has been built on a ridge which leads roughly from the northwest to the southeast between two deep valleys, one in the southwest and the other in the east and north.

According to dendrochronolgy the castle´s oldest parts date from around 1156 to 1165. Many parts of that time have survived:[15] First there is a round tower in the northwest of the castle, next to the entrance and directly above the moat. The main parts of the enceinte in the east date from this phase, too, as well as a second big tower which was built on a square ground plan and is situated on top of a small rock. Directly to the north of this tower two buildings can be found which are built on top of the enceinte: A chapel with a half-rounded apse and behind that to the north a big building with residential function, a so-called 'Palas'. To the south a tower provided access from the lower court to the chapel. Most parts of the enceinte in the west are younger and there are foundation walls of some more buildings which have not been identified yet (figs. 15-18).

It is not quite clear who built the castle because the first written evidence is from the year 1243, nearly one hundred years after the main parts were erected.[16] Most probably either the archbishops of Cologne or the Pfalzgrafen, a very important family of the higher nobility, were responsible for the building of this castle. That would also be a possible explanation for its outstanding architectural form with two main towers and a 'Palas' even in the 1160s.

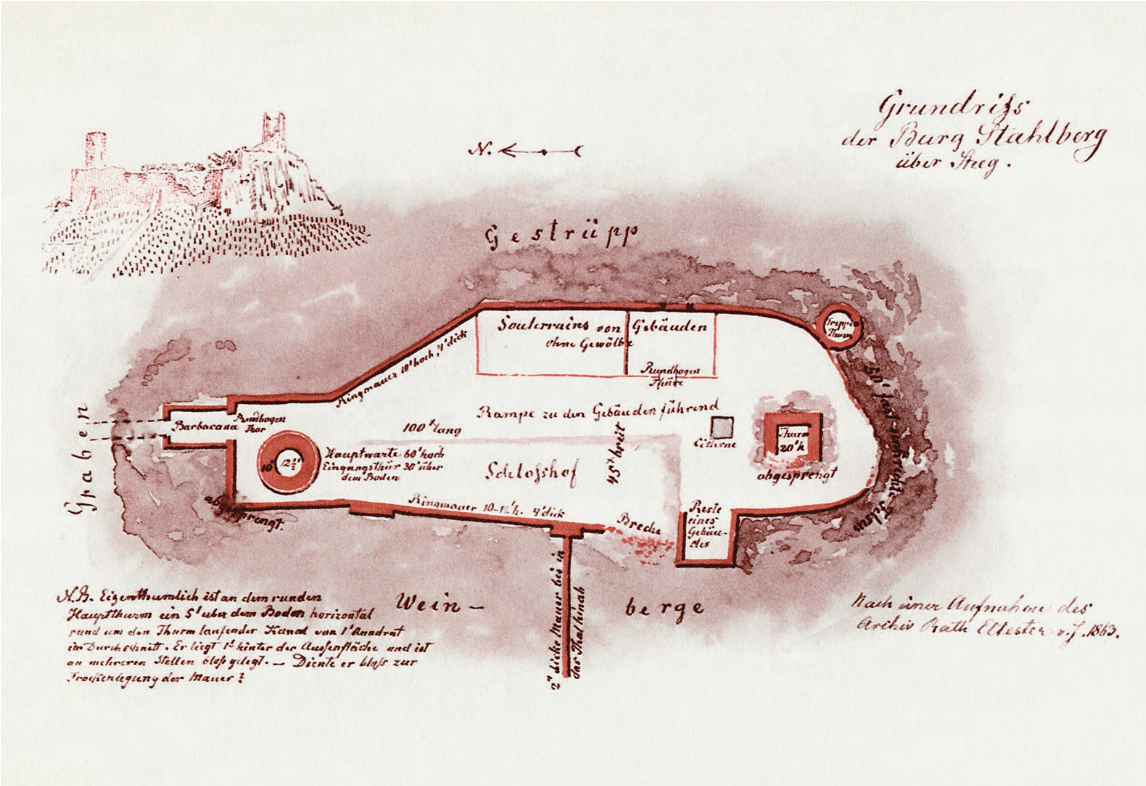

Fig. 15 Castle Stahlberg, plan from Leopold von Eltester, 1863.

Fig. 16 Castle Stahlberg from the west (2005).

Fig. 17 The round tower of Castle Stahlberg from the courtyard (2012).

Fig. 18 The round tower of Castle Stahlberg from the northwest (2005).

Today you must be careful not to miss the castle: only a small road leads up the valley in the west and from there another even smaller road branches off to the east and rises on the heights. It is then when you are just about two or three hundred metres away from the castle that you can see it. You get an impressive view from the northwest and you can see the round tower in the foreground at left and the square tower in the background at the right – the picture of a big castle with two main towers.

Fig. 19 The old road from Steeg to Castle Stahlberg today (2012).

But that road is a new one – in the Middle Ages the way from the town of Steeg to the castle went through the other valley where today there is only a small path (fig. 20). You can still see the former road because of the substructures but you cannot see the castle from there because of the woods. This way leads you up from the church of Steeg to the north and it follows the castle´s ridge in a northwesterly direction, slightly rising all the way. In the north of the castle it suddenly turns to the south and the passer-by is lead directly to the moat with the enceinte and the round tower behind it. This way was obviously arranged to impress the passer-by and to show them the architecture of this big castle because they are lead alongside the chapel and the 'Palas'. So consequently Achim Wendt who discovered the chapel tried to reconstruct what the tower, chapel and 'Palas' would have looked like for the passer-by when they were still intact and there were no woods (figs. 16 and 21-24).[17]

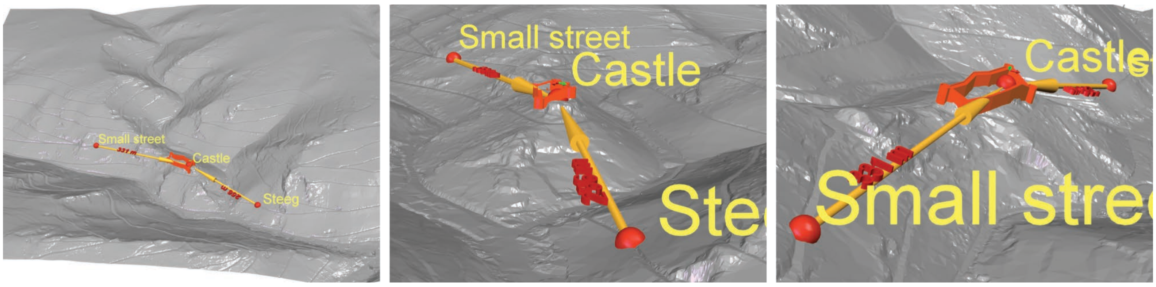

Fig. 20 Castle Stahlberg, schematic 3D reconstruction and distances and views from below, from Steeg (256 m), and from above, from Small Street (331 m), (2010).

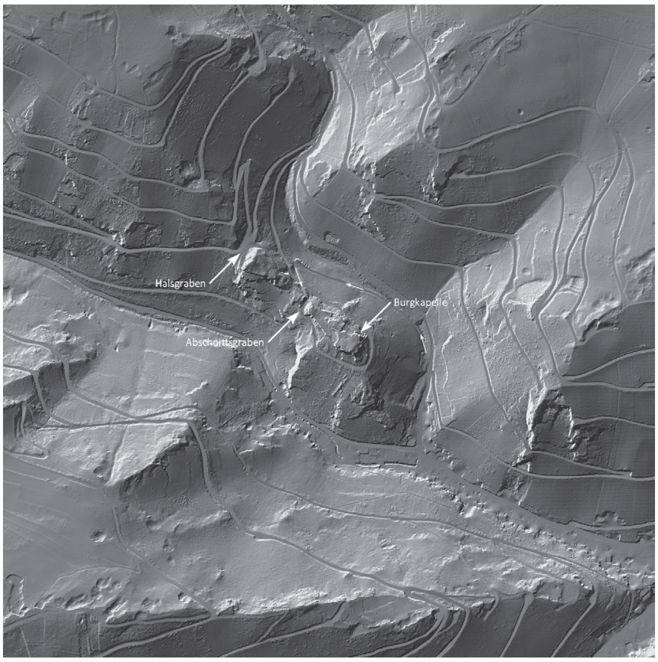

Fig. 21 LiDAR-scan of Castle Stahlberg and its surroundings (2011).

Fig. 22 Castle Stahlberg, building phases of chapel and 'Palas' (2011).

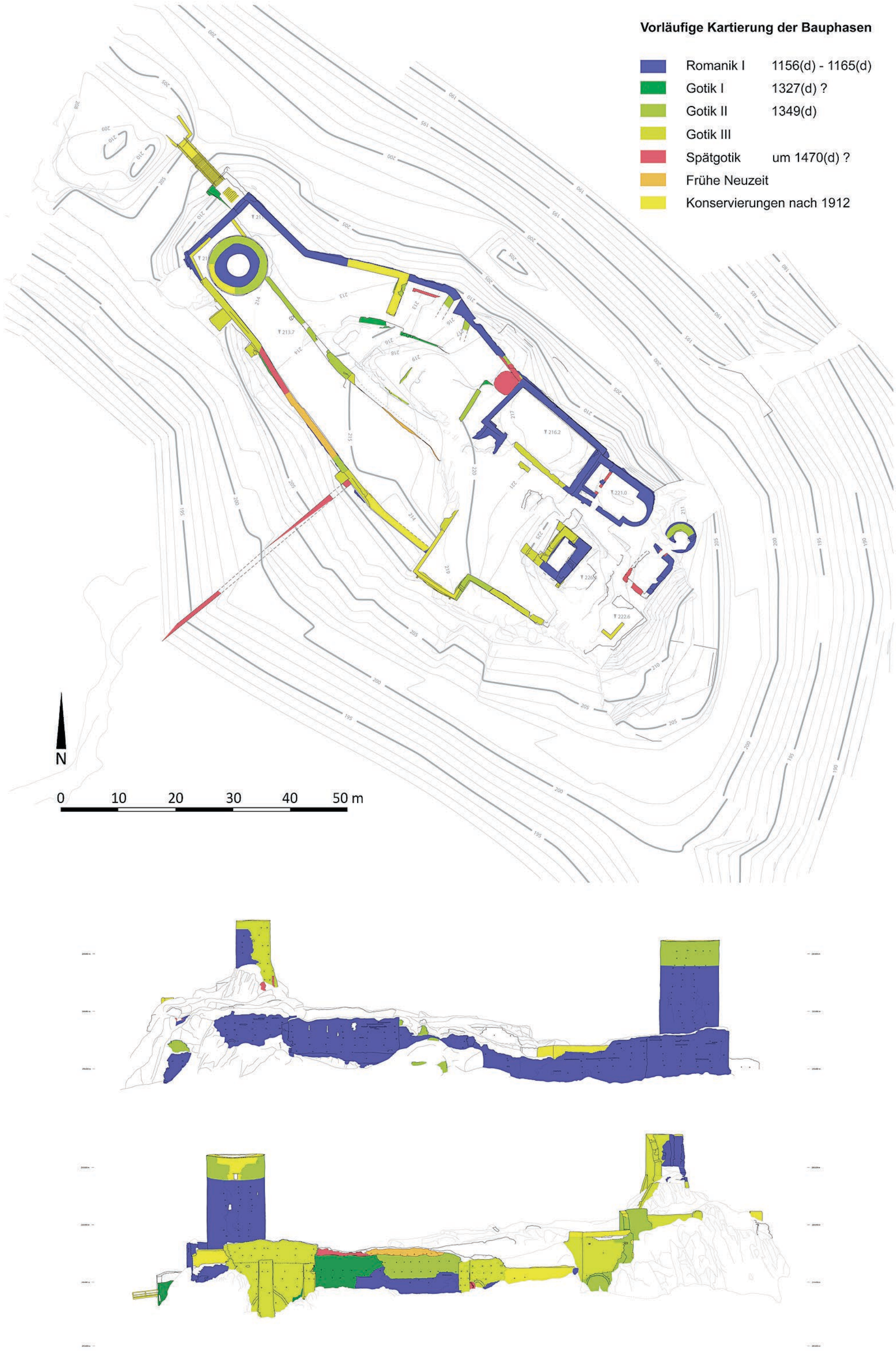

Fig. 23 Castle Stahlberg, building phases (2011).

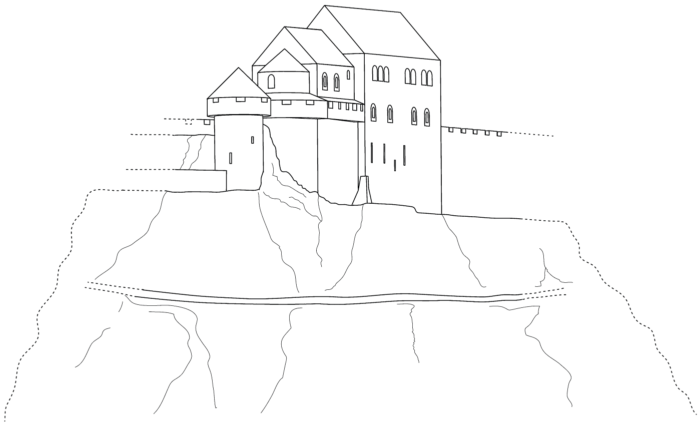

Fig. 24 Castle Stahlberg, reconstruction drawing of chapel and 'Palas' (2011).

Such illustrations are indeed quite helpful to show, and to analyse, what the contemporary viewer would have seen at the time. Going one step further, not only can many illustrations be derived from a full 3D reconstruction of the medieval castle and landscape, but even a series of such reconstructions accounting for the variation over time (4D reconstruction). This requires a very efficient method for the serial production of castle reconstructions, which is not possible using normal off-the-shelf 3D modelling software. Instead the authors have used the so-called Castle Construction Kit from TU Graz[18] for a first proof of concept for future projects. Based on the GML technology from Havemann[19] it gains its efficiency in 3D modelling from a procedural (generative) approach that allows plugging together parametric 3D building elements in a LEGO-style manner. The elements have built-in intelligence so that they can snap together geometrically, and each part can also be configured with a set of high-level parameters. Future projects should use the same method, however they will have to develop the prototype software further by adding more and more sophisticated and diverse geometric elements for castles (fig. 25).

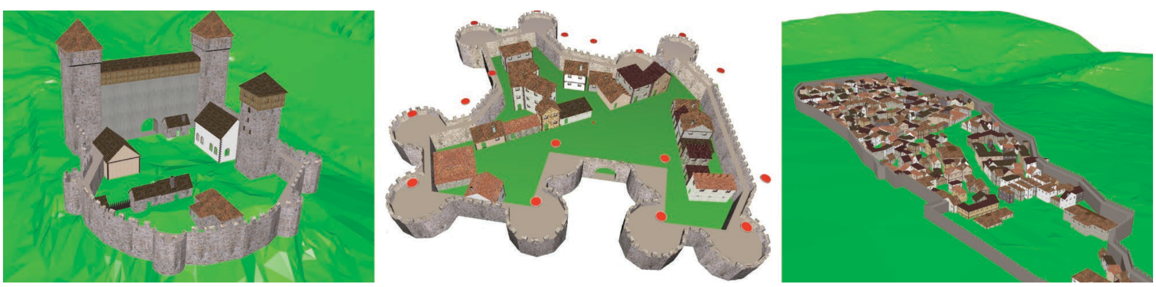

Fig. 25 Geometric building blocks of castles are snapped together to produce 3D reconstructions efficiently, up to the size of whole villages, according to facts and findings and adapted to the terrain (2005).

What is the use of such historic 3D reconstructions? We will show how the whole castle developed in the eyes of the passer-by coming nearer and nearer to the castle and how for example the two main towers rise in the background of chapel and 'Palas'. As we can choose the position of the point of view in the LiDAR-scans, we can take a view from different positions on the old road which led to the castle, i.e. we can reconstruct the situation as realistically as is possible. So we are able to create the real impression the castle may have left on the people in the Middle Ages – and that is even more important for art historical questions: Often virtual 3D models are very nice to look at, especially because you are able to fly around them and take a glance from every point of view as if sitting in a plane – but nobody tries to reconstruct what the people in the time of the building phase could see! How can we try to understand geometric figures of a ground plan of a complicated building if we look at the building in a way which was not possible for its contemporaries?

Using modern technology it is also possible for the historian to get an idea of what the view from a tower or any other part of the castle could be. To achieve this, the authors used a small multirotor UAV, normally used for the documentation of archaeological excavations, to reconstruct the view from the south eastern tower.[20] The day of the acquisition was very windy so a steady flight was impossible and we had to fly in manual mode and needed the support of H. Altenbach and A. Paulski watching the drift of the UAV from different sides. The resulting panoramic view nonetheless shows an impressive view into the valleys and the church of Steeg is also visible. The view was calculated from eight photos, shot by a Samsung NX-100 system camera with a 30 millimeter lens at an altitude of 20 meters above the castle floor. For the panoramic view we used the opensource-software 'Hugin'.[21]

A third example can show the use of the photogrammetry for analyses of castles. The idea is to use the so called 'Structure-From-Motion' (SFM) approach, which uses methods of Photogrammetry to reconstruct a three-dimensional object by a set of photos taken from different positions all around the object, to record a whole castle in 3D. This ambitious effort took place in March and June 2012 without using a UAV, which is still pending.

All in all, the authors shot about 1700 photos with a Canon 550D (18MPx), a Nikon D5100 (16MPx) and a Nikon D90 (12MPx) from different locations from the enclosed area, from the modern tower and all around the castle, moving only just a few meters at a time. It is necessary to check the photos afterwards for the correct exposure and white-balance in all areas, which is done using the particular software coming along with the cameras.[22] For the processing of the images we use VisualSFM by Changchang Wu from the University of Washington[23] which is freely available for academic use, although not open-source.

The next steps towards a 3D model are to find corresponding points in the photos, so every single photo has to be analysed and matched. After this step the software calculates back the positions of every photo. This step produces a sparse point cloud, showing a first rough 3D model alongside the positions of each photo. This data is used to calculate a dense model of the object, which takes some time, especially when using a large set of images as in this case. The following calculations were done on a high-performance PC at the Interdisciplinary Center for Scientific Computing at the Heidelberg University. The calculation of the corresponding points took 24 hours, while the sparse point cloud was ready after 20 minutes. The following calculation of the dense point cloud took another 24 hours.

Fig. 26 The quadrocopter at the takeoff position (2012).

Fig. 27 The quadrocopter flying at Stahlberg castle. The camera mounted is a Samsung NEX-100 (2012).

Using this dense point cloud the surfaces of the model can be reconstructed using the 'Poisson Surface Reconstruction' coming along with the open-source software 'MeshLab', developed by the Visual Computing Lab at 'Instituto di Scienza e Tecnologie dell'Informazione "A. Faedo"', Pisa.[24] The resulting model consists of 7.8 million points and 14.7 million triangles (faces) but is also showing some areas where no points could be reconstructed, usually because photos from above would be necessary, for example the moat in the north of the castle, as well as the whole area of the well in the north western castle area. The views from the tower are missing or their viewing angle became too flat for the calculation (figs. 26-41). Therefore the authors are planning to do another visit some time in 2015 using UAVs to acquire the missing parts of the castle and providing additional information to the existing calculations.

Fig. 28 ArchEye's quadrocopter flying over the castle Stahlberg (2012).

Fig. 29 View over castle Rauschenburg showing remains of the turret and the walls (2012).

Fig. 30 View from castle Stahlberg showing the church of Steeg (2012).

Fig. 31 A different view from above castle Stahlberg showing the church of Steeg (2012).

Fig. 32 Stahlberg, panoramic view, almost 360 degrees field of view (2012).

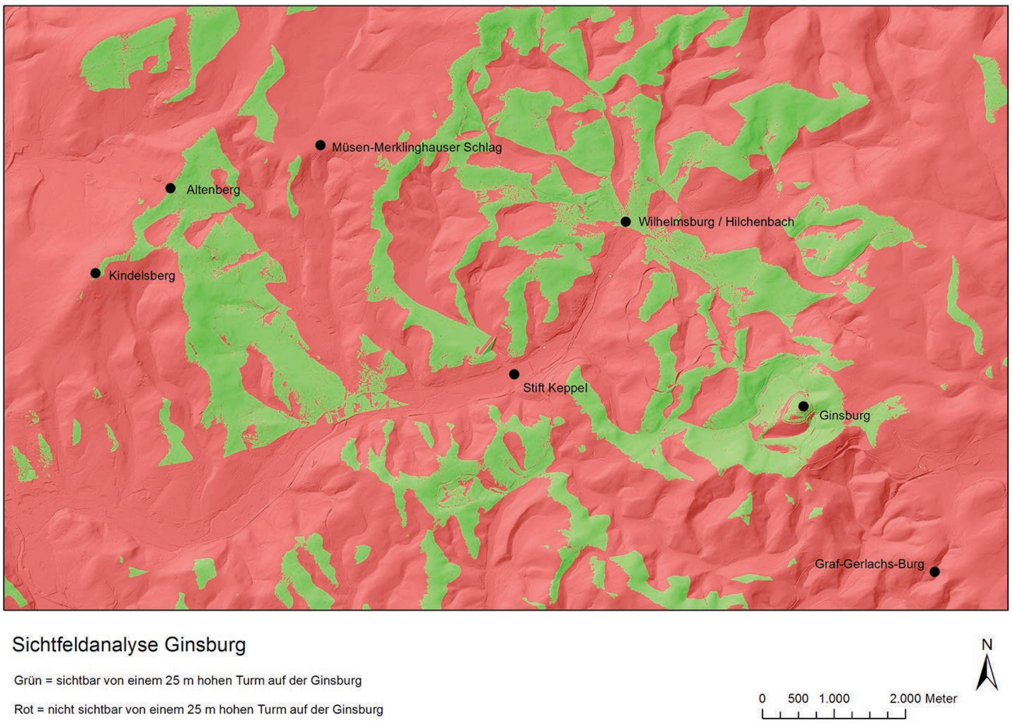

Fig. 33 LiDAR-scan of Ginsburg Castle. Green is what you can see from a tower of 25 m height (2012).

Fig. 34 Ginsburg, 3D model, detail of the northern castle wall (2012).

Fig. 35 Ginsburg, 3D model, view on the courtyard and the basement of the 'Palas' (2012).

Fig. 36 Ginsburg, 3D model, view from the northwest (2012).

Fig. 37 Ginsburg, 3D model, view from the east (2012).

Fig. 38 Ginsburg, 3D model, view from the south-southeast (2012).

Fig. 39 Ginsburg, 3D model, view from the south-southwest (2012).

Fig. 40 Ginsburg, 3D model, top view in orthographic projection (2012).

Fig. 41 Ginsburg, 3D model, view from the north (2012).

We will use the UAVs of the 'Project ArchEye' and its successor, the PhD-Project 'ArchEyeAutomatic'.[25] Two UAVs are available at the moment, one six-engine driven so-called 'Hexacopter' in coaxial engine order[26] and a bigger eight-engine 'oktocopter'. Both UAVs are based on the electronics developed and distributed by the German MikroKopter UAV platform,[27] consisting of a board for flight attitude regulation and a board for navigation functions with GPS-navigation and waypoint-navigation. The UAVs can carry a payload between 1.0 and 2.5 kilograms, allowing them to lift even a bigger reflex camera for up to 15 minutes. The UAVs can fly along a route calculated beforehand, concerning camera, lens and a target resolution on the ground and therefore trigger the camera at the right spots to get the photos necessary for the calculation of the 3D model.[28] Additionally it is planned to use ground control points to get a scaled and geo-referenced model of the castle.

The finally resulting model can be integrated into a GIS as a more precise starting point for viewshed-analysis, or even as a basis for a virtual reconstruction using an enhanced version of the Castle Construction Kit. We are convinced that we have the opportunity to broaden and deepen the art historical analyses and discourse with the help of LiDAR-scans and virtual reconstructions. They will enable us to obtain a new quality of insights and understanding of the tight relation of architecture and landscape so that we can create a new understanding of landscape for art history.

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Illustrations

Fig. 1-4, 6, 7, 9 Olaf Wagener 2008.

Fig. 5 Planarchiv der Generaldirektion Kulturelles Erbe Rheinland-Pfalz, Mainz.

Fig. 8 GML-Rendering of LiDAR-scan: Landesamt für Vermessung und Geobasisinformation Rheinland-Pfalz, 16.12.2010, AZ. 0322 28101 / 519336; analysis: Sven Havemann (GEO-Tiff Daten).

Fig. 10-14 LiDAR-scan: Landesamt für Vermessung und Geobasisinformation Rheinland-Pfalz, 16.12.2010, AZ. 0322 28101 / 519336; analysis: Olaf Wagener.

Fig. 15 Wendt 2011, p. 156.

Fig. 16, 18 Olaf Wagener 2005.

Fig. 17, 19 Olaf Wagener 2012.

Fig. 20 GML-Rendering of LiDAR-scan of Castle Stahlberg and its surroundings; analysis: Sven Havemann (GEO-Tiff-Daten). (16.12.2010)

Fig. 21 Wendt 2011, p. 153.

Fig. 22 Wendt 2011, p. 175.

Fig. 23 Wendt 2011, p. 157.

Fig. 24 Wendt 2011, p. 190.

Fig. 25 Castle Construction Kit from Gerth / Berndt / Havemann / Fellner 2005.

Fig. 26-28, 30, 31 Anne Paulski 2012.

Fig. 29, 32, 34-41 Christian Seitz 2012.

Fig. 33 LiDAR-scan: Geobasisdaten der Kommunen und des Landes NRW © Geobasis NRW 2012; analysis: Olaf Wagener.

[1] Concerning LiDAR-scans see Dorn and Wagener 2009, pp. 36-40 and Höfle and Wagener 2012.

[2] See Seitz and Wagener 2012 for details.

[3] Wagener and Schmidt 2013; Wagener and Schmidt 2010/11; Wagener 2006, pp. 368-372.

[4] For background information to the conflict and the politics of Archbishop Balduin of Trier see Eulenstein 2006 and Eulenstein 2007.

[5] Eulenstein 2006, pp. 84-87.

[6] Günther 1825, n. 242, pp. 495-498, especially p. 495 f. ‚[…] von desselben [=Erzbischof Balduin] vnsers Furfaren seligen Gezyten bysher vnbewonet vnd dadurch verwustet vnd vergenklich worden [...]'.

[7] Wagener 2003, p. 172 and Scholz 2004, pp. 240-248.

[8] Wyttenbach and Müller 1836-1838, vol. 2, p. 251. Translation in Zenz 1961, p. 55: 'Gegen sie zog Herr Balduin mit Heeresmacht zu Felde, schloß Eltz ein und befestigte das neu erbaute Baldeneltz in ganz erstaunlicher Weise. Hierdurch vernichtete er die Macht von Eltz.'

[9] Thon and Ulrich 2007, p. 53.

[10] See Kirchschlager and Stolle 2006.

[11] In the last years art historical research took place in Castle Eltz, oral information from Lorenz Frank, Mainz. A publication of the results is intended.

[12] See Urban 1996, pp. 69-71; Wagener 2003 p. 171 f.; Wagener and Schmidt 2010/11, pp. 219-230.

[13] This phase can in its dimensions and structure be compared with the so-called Aachener Schanze, a siege castle against Castle Rheinberg in the Wisper Valley near Mainz, built 1279/80, see Wagener 2006, pp. 362-365. It is not easy to judge how much space a trebuchet needed, see Küntzel 2006, pp. 357-360.

[14] See Speight 2000 and Wagener 2006.

[15] See Wendt 2008 and Wendt 2011.

[16] Koch and Wille 1894, p. 27, n. 489; Knipping 1909, p. 163, n. 1099.

[17] Wendt 2011, p. 190.

[18] See Gerth et al. 2005 for details.

[19] See PhD thesis Havemann 2005 for details.

[20] The UAV is from 'Project ArchEye' at Heidelberg University, operated by C. Seitz: www.archeye.de.

[21] http://hugin.sourceforge.net.

[22] In this case we used 'ViewNX' for photos coming from the Nikon cameras, while the photos of the canon where processed using 'Digital Photo Professional'.

[23] Wu, Changchang, 'VisualSFM: A Visual Structure from Motion System', http://ccwu.me/vsfm/, 2011 and Wu et al. 2011.

[24] http://meshlab.sourceforge.net.

[25] The PhD-project is realized at the working group 'Optimization in Robotics and Biomechanics' (ORB) at the Interdisciplinary Centre for Scientific Computing, Heidelberg University. Supervisors are Prof. Katja Mombaur (ORB) and Prof. Matthias Untermann (Institute of European Art History, Heidelberg University).

[26] In this constellation, the UAV has three arms with two paired engines, one facing to the top and the second to the ground, rotating in different directions and thus minimizing vibrations but also resulting in a more compact design.

[27] www.mikrokopter.de.

[28] This software was developed by C. Seitz for Project ArchEye.

Building Knowledge Spaces

Scientific Reconstruction and Modeling of the Medieval City of Bamberg

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Project Description

Within the framework of the project '4D City Model of Bamberg around 1300', run by the Professur für Bauforschung und Baugeschichte of the Otto-Friedrich-Universität Bamberg in cooperation with the Department of City Planning, City of Bamberg, funded by the Oberfrankenstiftung and the Städtebauförderung, a scientific reconstruction of medieval Bamberg as it was around the year 1300 is being created that can be combined with the existing digital model of the city as it is in the present day. '4D' is the expression for the ambitious goal of incorporating the dimension of time into the project, in addition to the three dimensions of space and of building not only a visual reconstruction but also a multidimensional knowledge space. This is being done by openly showing and recording the different stages leading to the final reconstruction, by combining the visualization of historical situations with scientific institutions and references, and finally by linking the virtual model to the official web-based model of the city of Bamberg to gain sustainability and a broader range of users, including the World Heritage Centre Bamberg. Through this combination, the development of the historical town and the substantial remains and changes in today's city can be seen and virtually explored. The close relationship of the present day to the city as it was, such as the location of the streets and individual buildings, becomes easily comprehensible. This is achieved through the use of geodesic data for all of the digital models, and through the coordination of the programs used and the way that the information is depicted (fig. 1). The exact spatial relationship of the surviving historical construction material within modern constructions is interesting for historical sciences as well as for preservation and renovation projects and future city planning. The virtual model is an excellent basis for integrative uses of researchers and the city's authorities as well as tourists and 'laymen'.

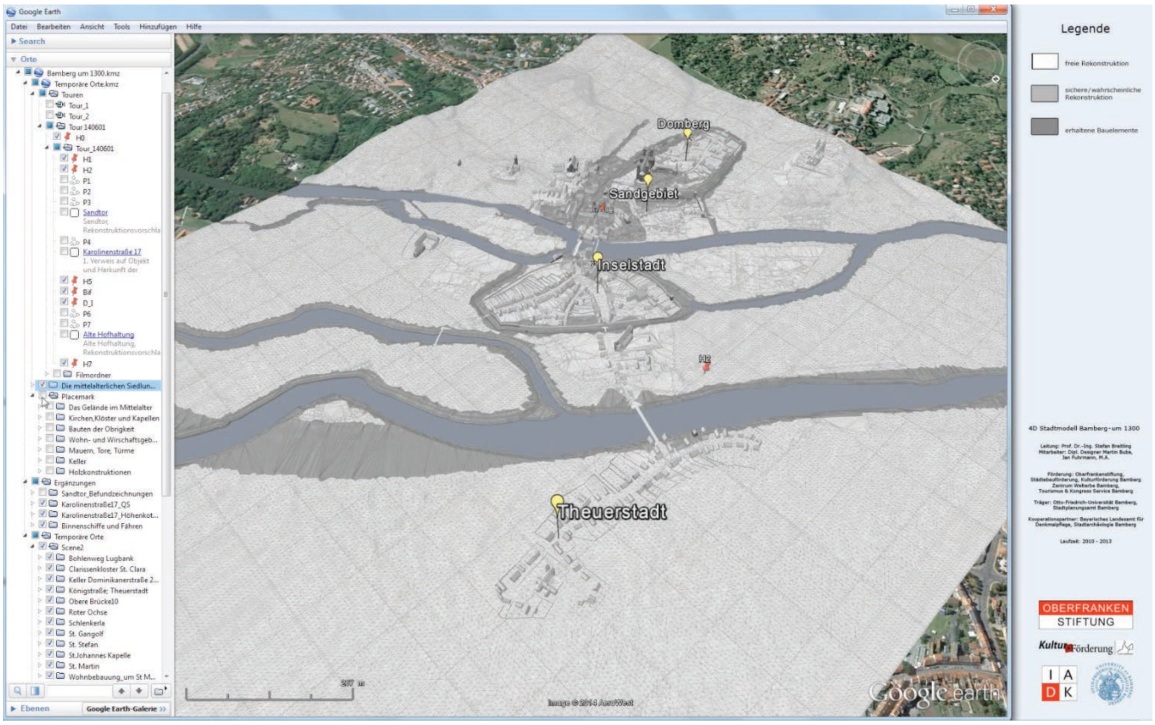

Fig. 1 The digital reconstruction model of the medieval city of Bamberg at around 1300. Bird´s eye view from the northeast with the three medieval centres Theuerstadt, Inselstadt and Bergstadt. Interactive Google-Earth-Surface with navigation panel, lists of buildings and tours (2014).

The idea of a digital city model following historical development with multiple layers of time was already developed in 2008 by the World Heritage Center Bamberg (Welterbezentrum) and the Department of City Planning (Stadtplanungsamt), and was presented in front of the General Assembly of the International Council on Monuments and Sites (ICOMOS) in Canada. In 2014 the new model was presented at the 'MS Wissenschaft', an initiative of the German Ministry of Education and Research (Bundesministerium für Bildung und Forschung).

Scientific Reconstruction of the City of Bamberg around 1300

Having started in 2010 and running for three years, the '4D' project is meant to be a continuation of current work. Scientific support for the project is being provided especially through the research of the Bayerisches Landesamt für Denkmalpflege (Bavarian State Office for Building Preservation), the work of city archaeologists, the World Heritage Center, and a number of additional partners. The volume *Die Kunstdenkmäler von Bayern, Stadt Bamberg, Band 1: Das Stadtdenkmal Bamberg* (*The Monuments of Art of Bavaria, City of Bamberg, Volume 1: The Municipal Monument of Bamberg*), published by the BLfD (Bayerisches Landesamt für Denkmalpflege) in 2012, explains the necessary requirements for the reconstruction of the medieval city and its objective of making known facts about the medieval history of Bamberg accessible.

A number of new methods have been utilized in this project. Project labor has been divided between different institutions, and new scientific modeling and reconstruction methods have been used as well. The reconstruction of medieval Bamberg keeps a distance from the photorealistic model of the city as it is today, in order to give the observer's fantasy and intellect room to play. The ultimate goal was to combine the present day with the historical city, so that the historical basis of the remaining building structures as well as the city's development becomes obvious (fig. 2).

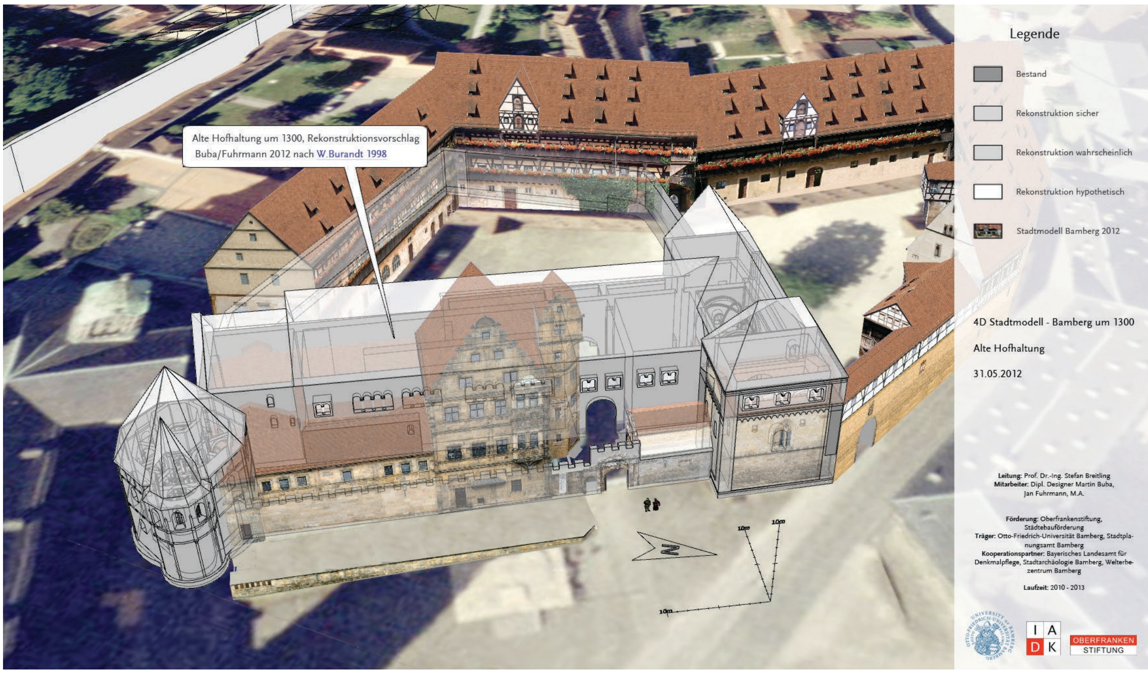

Fig. 2 Bamberg, Alte Hofhaltung at around 1300. Overlay of the medieval palace with the photorealistic model of the surrounding area, as it is today (1998/2012).

In the first stage of the project, geoscans from the Bavarian Land Survey Office (Landesvermessungsamt) were transformed into meshed vector geometry, in order to show changes in the relief model and also portray the historical path of the river, the height of the (likely) water level as it was around 1300, and other known deviations from the relief of the modern city. Reconstructions of medieval buildings and other elements of the city, whose locations are known due to preserved remains, can be precisely fit into the model (fig. 3).

A team of archaeologists, building historians, and building researchers is collecting the historical information and working on suggestions for the reconstruction. One deciding criterion for the scientific nature of the model is the confirmability of individually selected solutions.

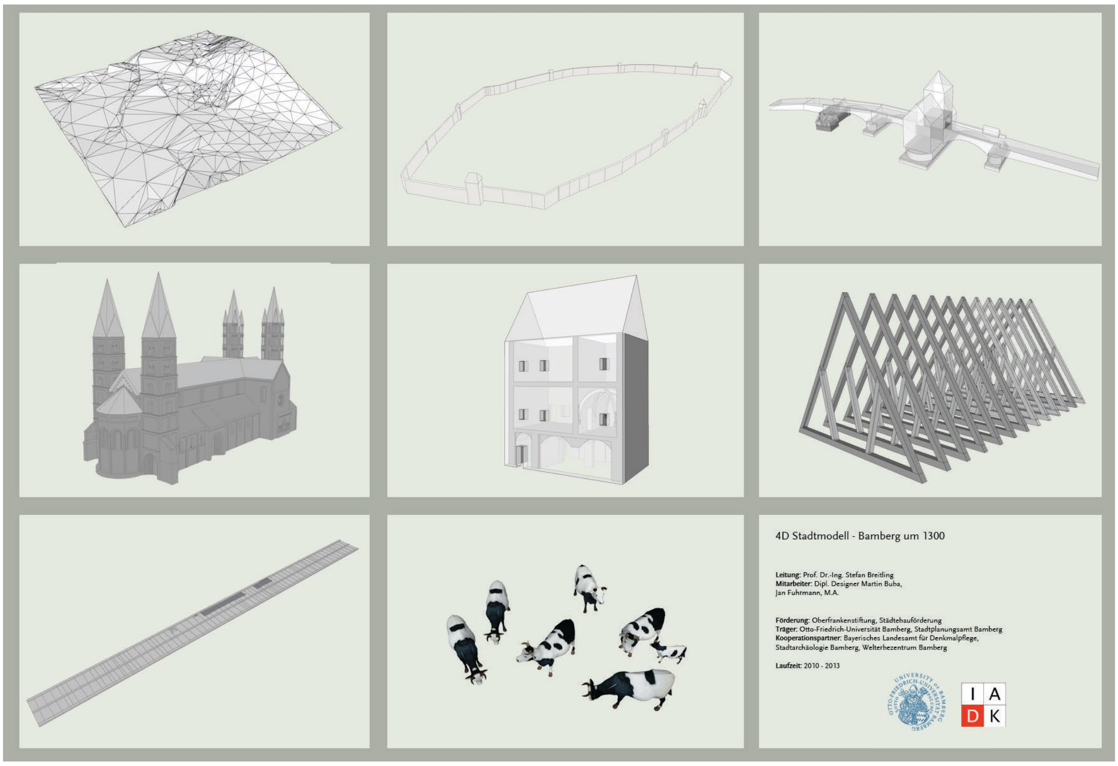

Fig. 3 Elements that make up the medieval city. Historical topography, defences and walls, bridges, churches, houses, historical constructions such as roofs, pathways, elements of the cultural landscape (2012).

This is because in a digital or analog model, everything must be constructed in an unambiguous manner, and nothing can be graphically blurry. However, in many areas of the city or a single building little to nothing is known. Here, in order to close the gaps, researchers are resorting to the use of analogies in local or regional construction. In addition, five stages of certainty of knowledge are included throughout the reconstruction, coded by the degree of detail and color and level of intensity. Archaeological finds from medieval Bamberg, which can be seen in the city, or that have been found through archaeological digs and examinations of historical buildings, are reflected in the depiction of details in the model. Constructions that certainly existed are marked in dark gray. Building elements that had certainly been there, but which are no longer present, are shown in a lighter gray. Building components that are reconstructed using only vague analogy are shown in a even lighter color and are transparent (fig. 4). They are, however, still necessary to round out the (presumable) original appearance and the comprehensibility of the depiction.

A scientific model must also offer the user the possibility of stepping into the discussion about recommendations for the reconstruction. In order to clarify the decision-making process during construction and also protect the achievement of the creators, every recommendation for the reconstruction of a building or building component is referenced in three stages.

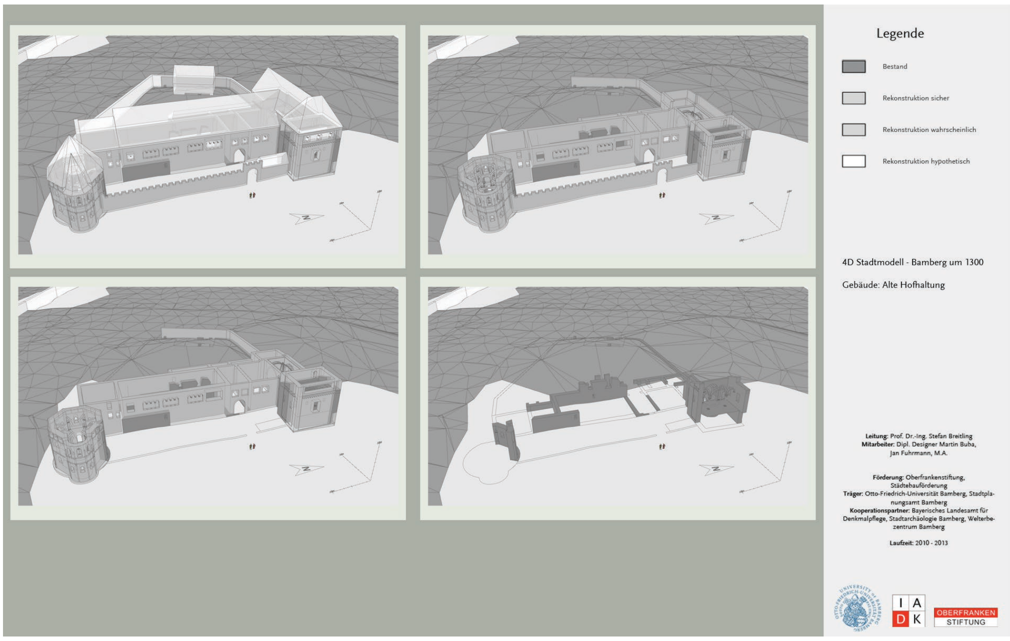

Fig. 4 Bamberg, Alte Hofhaltung at around 1300. Reconstruction with four levels of credibility. Remaining fabric, certain reconstruction, probable reconstruction, hypothetic reconstruction (2012).

In the first, every reference to a certain construction is cited in the model itself. In the second, the used material is stored and the questions that are associated with the building component, and arguments that led to the final reconstruction, are explained. This data base is an integrated part of the model and can be used by the cooperating institutions (fig. 5).

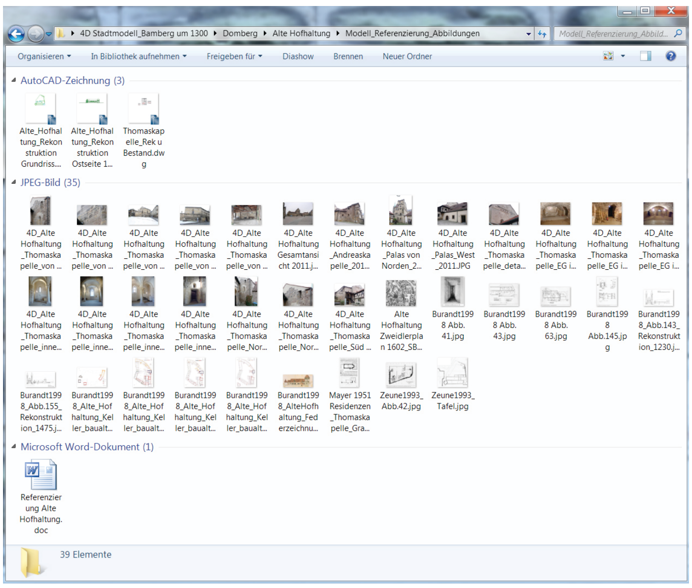

Fig 5 File sheet with collection of basis data for the reconstruction model of the Alte Hofhaltung at Bamberg and commentary on the reconstruction process (2012).

In the third, important findings and additional depictions are incorporated. The final result is a model that can be checked for accuracy, explicitly allows for later changes and corrections, shows gaps in current research, and also shows a path to additional research and new debate about the construction history of the city of Bamberg (see film, fig. 6).

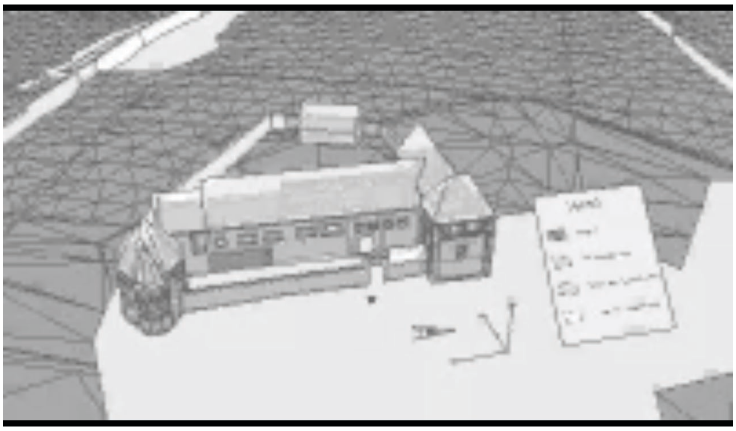

Fig. 6 Animation film: The Alte Hofhaltung at Bamberg at around 1300, remains and architectural reconstruction (film still, 2012).

Possible Applications, Linkage, Sustainability, and Possibilities for Expansion

The basic structure allows for the long-term usage of the model through different users, even after the conclusion of the project. There are already plans for the model to be retrievable online. The digital city model can also be further developed. Users can interactively browse the history of the city and individual quarters, and additional time periods can be added. The implementation of the Zweidler city map of Bamberg from 1602 into three-dimensional geometry is already in progress. The reconstruction model can always be expanded with new details and themes. In doing so, there is a running portrayal of historical and world heritage elements in the city. This is especially important in the conveyance of historical significance, which can remain dormant in the historical buildings of Bamberg. In the virtual world, connections and aspects can be made clear that are otherwise difficult to show or are simply no longer accessible (fig. 7).

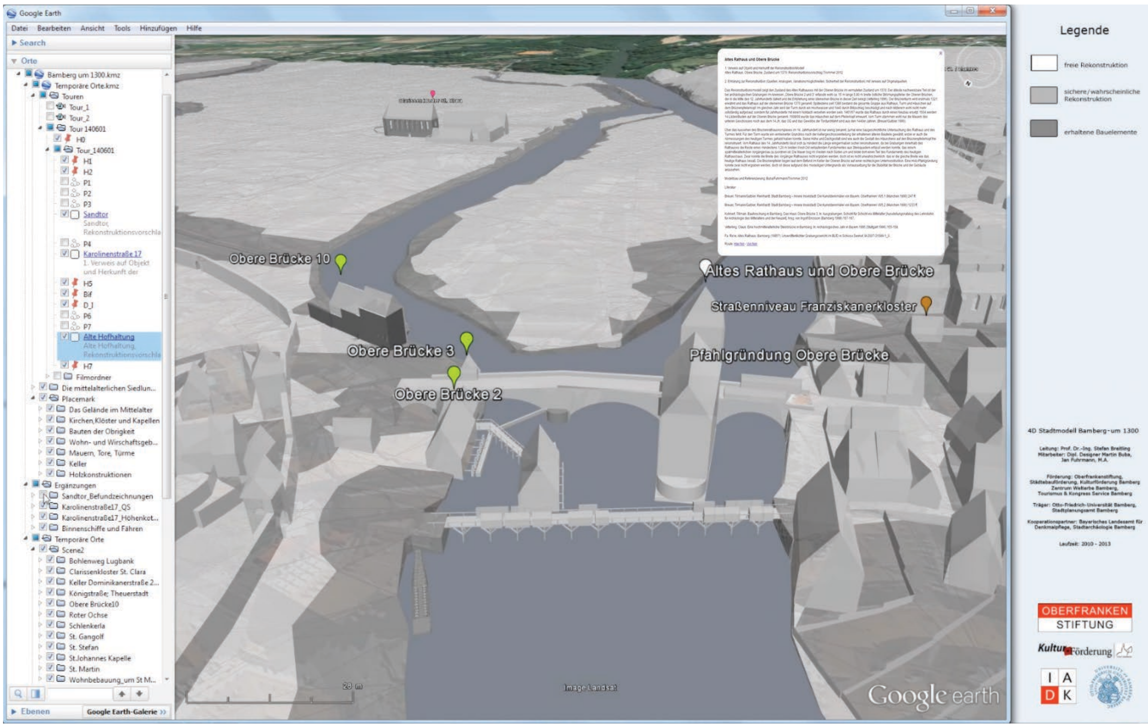

Fig 7. The digital reconstruction model of the medieval city of Bamberg at around 1300.
Bird´s eye view from the northwest towards the center with town hall,
bridges and other elements of every-day life (2014).

An important user and communicator for the 4D city model of Bamberg is the World Heritage Center of the City of Bamberg. In addition to information about city history, all sorts of additional, geo-referenced topics can be added to the map that can help touristic development of the city's world heritage characteristics. During city tours, via a handheld or smartphone with Augmented Reality (Mobile HR), it would be possible to give people visual clues about their location and information about the buildings in the area. In addition, different user groups could have thematic virtual tours. Projects that already exist, like the interactive use of the map as part of the 'Beam me up!' project of the Department of City Planning, which allows for users to learn about the complexity of the cultural heritage of Bamberg in a playful way, opens up a wide field of scientific knowledge spaces.

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Illustrations

Fig. 1 Breitling/Buba/Fuhrmann 2014.

Fig. 2 Breitling/Buba/Fuhrmann/Uni Bamberg 2012, building research by Burandt 1998, nowadays city model by Carlo Schramm, Stadtplanungsamt Bamberg 2012.

Fig. 3 Breitling/Buba/Fuhrmann/Lunemann/Trommer/Mattern/Uni Bamberg 2012.

Fig. 4 Breitling/Buba/Fuhrmann/Uni Bamberg 2012.

Fig. 5 Breitling/Buba/Fuhrmann/Uni Bamberg 2012.

Fig. 6 Breitling/Buba/Fuhrmann/Uni Bamberg 2012.

Fig. 7 Breitling/Buba/Fuhrmann 2014.

Virtually Rebuilding the Palace of Vila Viçosa in Portugal

From the Present to the Time of D. Teodósio I (16th Century)

Ana Catarina G. Lopes (EAUM – Escola de Arquitectura da Universidade do Minho / CHAM – Centro de História de Além-Mar, Portugal)

Studying the Palace of Vila Viçosa (fig.1) as an element of Portuguese architectural history became essential to the FCT research project *De Todas as Partes do Mundo. O Património do 5.º Duque de Bragança, D. Teodósio I / All his Wordly Possessions. The Inventory of the 5th Duque of Bragança, D. Teodósio I*.[1] Since the beginning of the project, the research team has been working on an inventory of extraordinary value, revealing the goods, the cultural and intellectual interests of an important aristocrat of the 16th century, D. Teodósio, describing in detail and giving us a rare and amazing view of the material world of a prince of the Portuguese Renaissance. The *Duque* was from one of the most powerful families of his time. His father, D. Jaime (who was nephew of the king D. Manuel), ordered the construction of a palace in 1501 in southern Portugal to mark the land that the king had offered him. I began collaborating with the research team in order to virtually reconstruct the Palace of Vila Viçosa and its surroundings, in the time of D. Teodósio I (the first half of the 16th century).

Fig. 1 Palace of Vila Viçosa, Évora, Portugal (2012).

The Major Aims of the Ongoing Work Framed in the Workshop *Virtual Palaces II*

As an architect and a teacher in the field of the history of Portuguese architecture, the interest for the study of architectural heritage has aroused in me a special interest in virtually designing and reconstructing architectural structures as material to be deeply analysed, thus producing know-ledge, especially in its interaction with the territory and the cultural contexts that produced historical monuments. The idea of participating in an interdisciplinary forum to discuss the contribution of virtual reconstructions and its various methods was something I found of extreme interest. It allowed for obtaining a greater insight into architectonic structures and their physical space, rhetoric representations and how to better inform the scientific community on the investigations' results.

D. Teodósio was responsible for the renewal and extension of his family's residence, turning it into a palace that followed the most erudite Italian models – a clear demonstration of his adherence to what was most advanced in European architecture of that time. Several changes have been made to the palatial spaces until the present day, but with the documentation under study and through an interpretation of the existing building, we believe one can virtually rebuild its architecture in a unique approach to the history of this ducal house.

The short communication I was able to do[2] wished to report on how we were developing this work, sharing the possible methods I have been using and comparing them with some case studies that I have been analysing, framing the study of the Palace of Vila Viçosa (from the present to the first half of 16th century). The work aimed to include the registration of all the metric and geometric information – architectural and topographical surveys, counting with photogrammetry. We have always considered the architectural survey a fundamental tool to proceed with rigorous studies of the historical structure. It is fundamental to acquire it, as it allows to test, clarify the types, forms, functions and geometries of this complex, allowing to launch interpretations related to the artistic domain and functional programme, as well as the evaluation of the possible impact of different construction phases.

At the time of the meeting in Munich, the research project was already underway for some time, but the architectural work of virtual reconstitution was really just starting and already had several process changes. The short presentation became an opportunity to report how we intended to develop the work. And for that it was important to reflect briefly about one or two examples of other case studies we have carried out. Its results have been quite satisfying and, therefore, we wanted to apply the same methodology to study the Palace of Vila Viçosa.

Other Case Studies

Working as a research assistant at the *Centro de História de Além-Mar (CHAM)* has allowed me to be part of some research projects about castles and military settlements built in the first half of the 16th century by the Portuguese overseas, particularly in Morocco (figs. 2-4). The drawings and three-dimensional representations reproduced results of architectural and topographical surveys, including photogrammetry. The works always begin with the registration of all the metric and geometric information of the architectural remains. Sometimes we resort to the use of technology, on other occasions we work with the support of more traditional methods, usually adapting the best tool to each situation. At each time of the fieldwork it is necessary to decide what information is essential and what is detrimental to capture the formal features of the architectonic object we wish to comprehend. The architectural survey is fundamental to proceed with rigorous studies of the historical structure, but sometimes it is hard to decide where to exactly point out the laser to accurately locate and measure damaged structures. At other times, it is impossible to reach the entire spaces with the topography equipment or it simply becomes easier to do some manual measurements, using a triangulation method overlapping some points topographically calculated as a common axis vector. AutoCAD is the software I use to work out the metric and rigorous data as vector information of the current state of the building, with all its formal characteristics. The collected material is then processed and produced in 2D and 3D reconstructions in terms of seeking interpretations and studies produced on the architectural work. It is always possible to go back and remake these drawings and handle their representativeness. After this, I export the data to another program – SkechUP, that greatly simplifies choosing views, imposing shadows caused by simulated sunlight and deciding the graphical representation. As a final treatment of the images produced, we use Photoshop and Illustrator. We never seek realistic representations, but we prefer to create virtual models that can be updated at any moment.

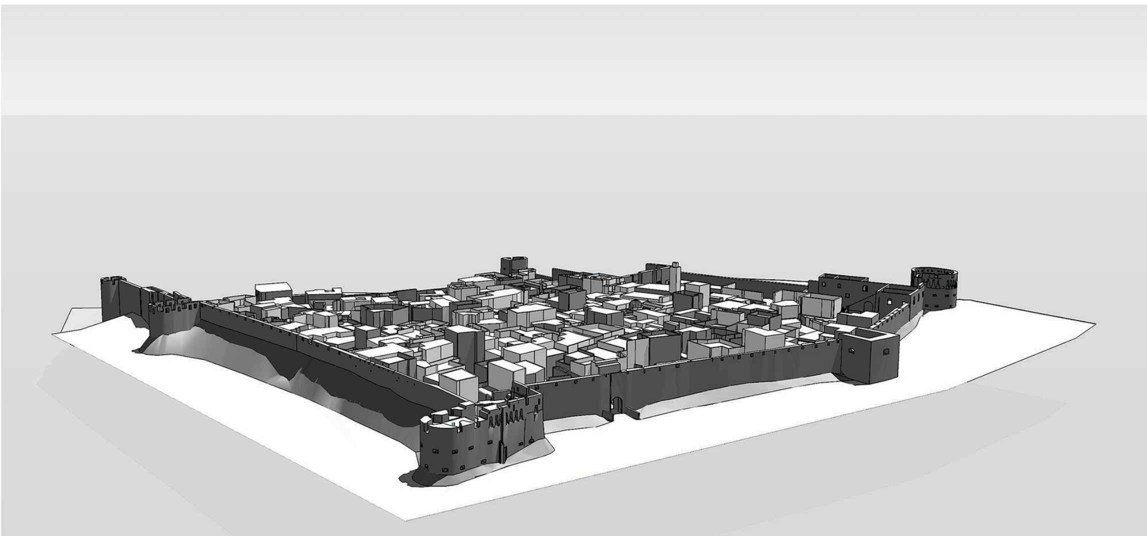

Fig. 2 Three-dimensional reconstruction of the Portuguese military settlement and urban occupation in Azemmour, Morocco, 2009.

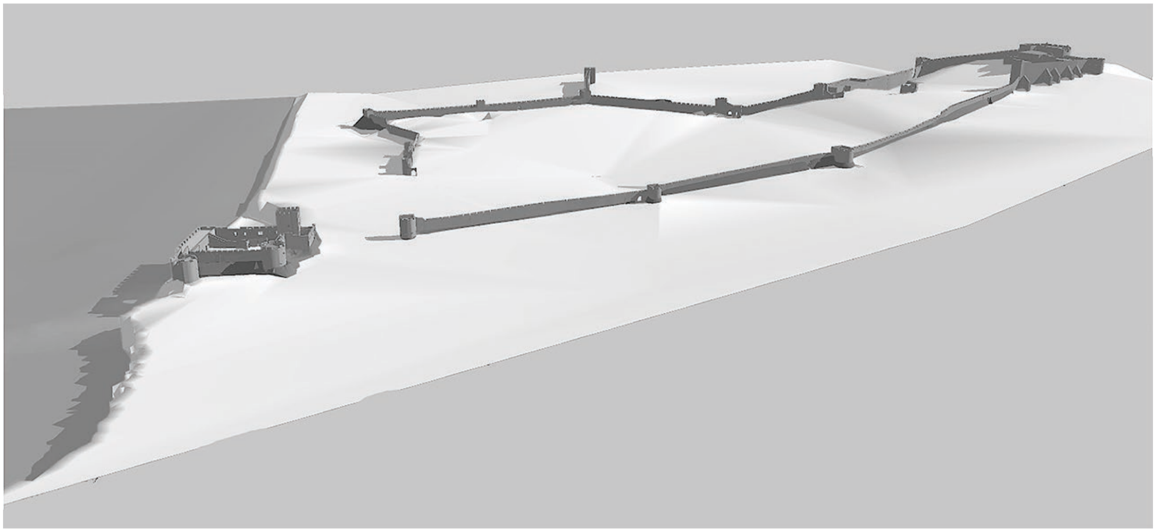

Fig. 3 Three-dimensional reconstruction of the Portuguese military settlement in Safi, Morocco, 2010.

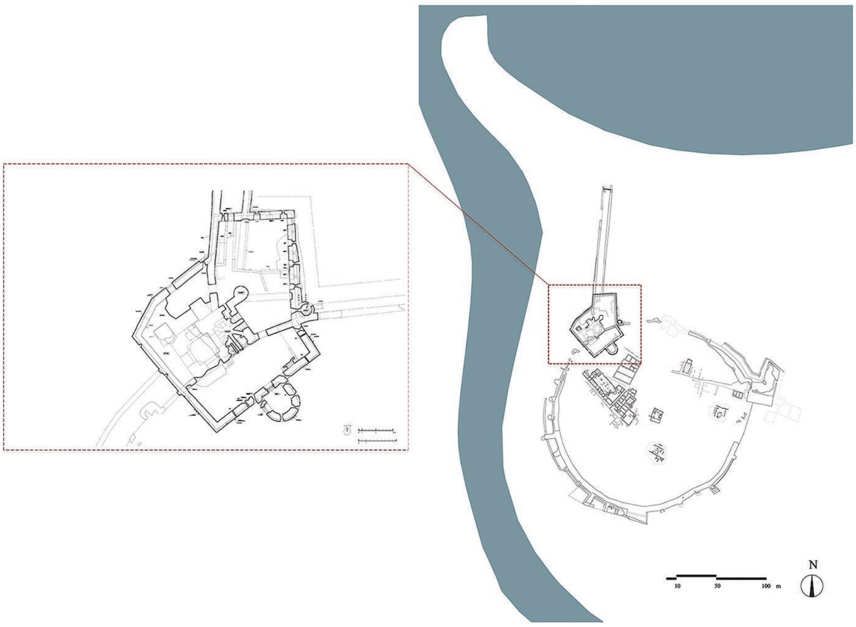

Fig. 4 Plan of the Portuguese military settlement in Ksar – Seghir, Morocco (survey of the remaining ruins) and close up of the citadel's plan, 2011.

These are the fundamental tools that permit us to test and clarify the geometries of the elements under study, allowing launching interpretations related to the artistic domain and functional programme, as well as the evaluation of the possible impact of different construction phases.

Some of this work is also important as testimony of built heritage, which sometimes is on the brink of disappearing. This is the case of the *Château de Mer* in Safi, which is about to be destroyed by the sea. In Azemmour, the urban and architectonic studies have defined the best sites for archaeologists to carry out their excavations. With their findings, we made some virtual reconstructions of structures that disappeared with time (fig. 5). As an architect, my vision will always be more focused on issues like metrics, ratios, geometry, materials and construction systems. Collaborating with other professionals, particularly with surveyors, archaeologists and art historians has shown me that the crossing of several disciplines can produce the real (re)creation of knowledge for the reconstruction of architectural spaces and life styles of the cultural heritage.

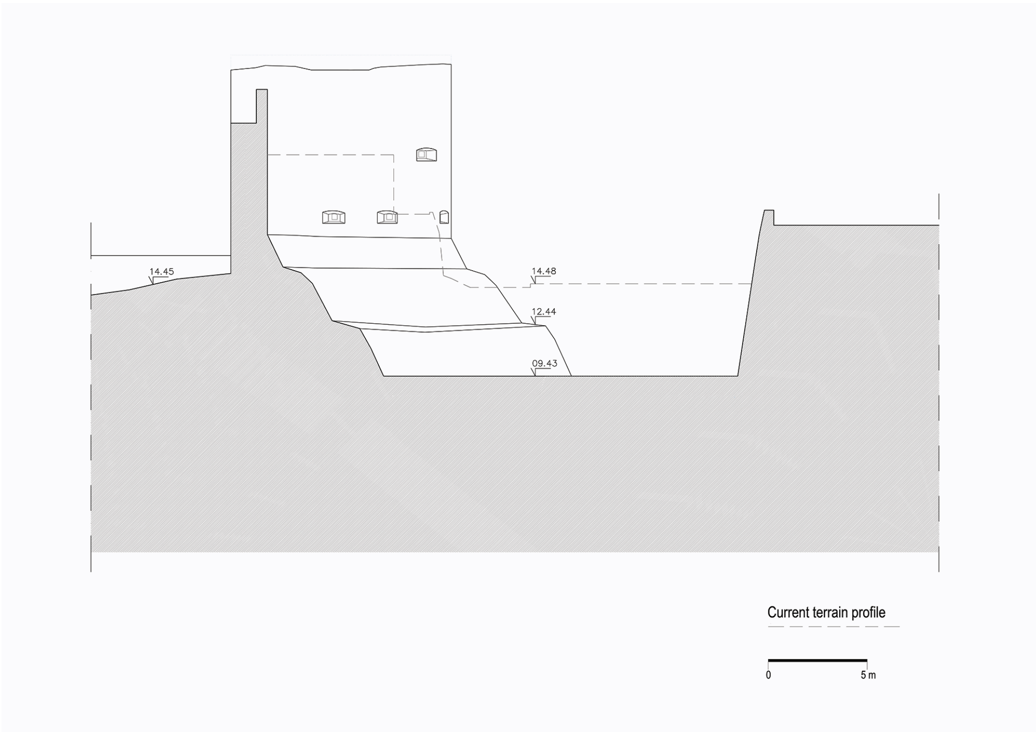

Fig. 5 Reconstitution of the bulwark excavated by the archaeologists recovering the moat section, Azemmour, Morocco, 2009.

I studied proportions, ways of building, tested the knowledge of the Portuguese builders concerning the treatises of their time and verified if the workmen complied with the orders of the King that have been interpreted by historians. The analysis of the data obtained allowed us to identify some interesting mathematic rules and geometries used by the constructors, understanding their architectural solutions to the challenges they had. It was also possible to overlay the three-dimensional reconstructions with coeval iconography to check the accuracy between representation and reality. This joint work enabled an improved understanding of its continuous overlaps and multiplied conceptual elements that were introduced over time, so we could better read its architecture and virtually rebuild it in its original form.

Studying the Palace of Vila Viçosa

We planned to do the same kind of work and subsequent research on the Palace in question. Today, the palace serves as a museum and belongs to a foundation established in the early 20th century: the *Fundação Casa de Bragança,* with which we had to establish some protocols. Our study focuses on the structures that constitute the ground floor and the noble floor, as it is known that the third level is the result of a more recent construction campaign. But these are the main floors of the museum, which is open almost every day of the week and weekend and receives a huge number of visitors. This could hinder the progress of measurement, drawing and observation fieldworks, and all this made it necessary to coordinate things between us and the staff and officials of the palace.

We started studying the palace as it is nowadays, starting from a few architectural drawings that report its physical status over time, going back to 1845. Together with the meager historical information, we were just learning a little more about the building history, crossing information with the rest of the research team, recognizing the physical changes that its architecture suffered with the continuous periods of construction.

We already had a strategy and a timetable for the survey work, when we were informed that there was no authorization to develop this kind of effort, because it could jeopardize the safety of the museum and its exhibits. Thus, we decided to develop an alternative approach – we would have to use the existing drawings to compare different stages of the building's existence. But we soon realized that those plans were not truly realistic and perhaps, we could be compromised to achieve accurate results of architectural historiography. We wanted to recognize and draw the functional distribution of the Palace and for that it will be very important to cross the possible analysis of those drawings with the documents that the inventory of D. Teodósio includes (such as letters, account books, descriptions of preparations for family weddings and their festivities taking place in the residence and even records of building work and its payments, including measurements of what was executed).

Moreover, there was still no graphical database for us for working on the virtual models. We decided to draw over the most recent plans, line by line, to have a basis to work on (figs. 6-7). Having done this, we asked for permission to walk through the Palace, only to make notes on our drawings about some of the interior walls and even some ceilings and doors that have been changing until the last few years. We also requested to register only a few measurements just to serve as a comparison with our projections. This appeal was accepted, and we visited Vila Viçosa for this fieldwork. At that time we already had the plans that resulted from combining information from the different existing drawings. The outcome of the overlapping between floors had an evident failure, once almost neither of the main walls had a structural overlay (fig. 8). We were dealing with a large degree of uncertainty and definitely would have different results than we expected to obtain with our usual process doing archaeology of the architecture. The ancient plans we had access to are ideal representations of the Palace, with too many orthogonal angles – a constructive stiffness that we know is not usual in these buildings. And drawing over some scans brings several irregularities of perception. One can read the spatial relationships, but not the built reality. With this outcome, and because it was really a waste of opportunity to develop such a study without being able to make a proper architectural survey in a building that still exists, we got back to having the authorization to carry out the work as we had envisioned originally.

Fig. 6 Drawing of the ground floor of the Palace of Vila Viçosa, obtained by vectorization of overlapped scans of the existing plans (2012).

Fig. 7 Drawing of the noble floor of the Palace of Vila Viçosa, obtained by vectorization of overlapped scans of the existing plans (2012).

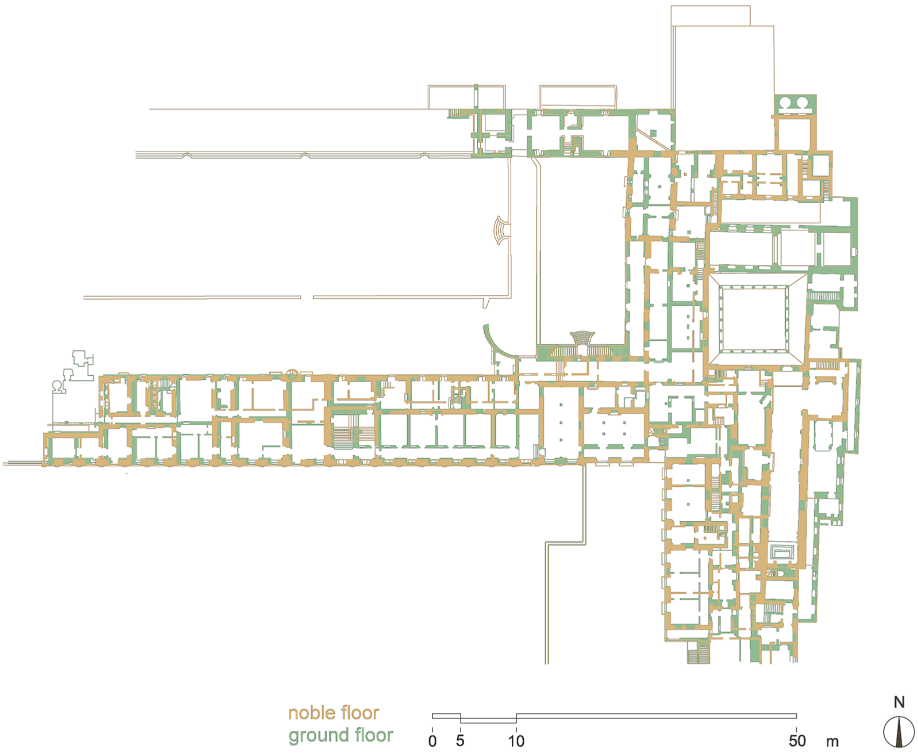

Fig. 8 Superimposition of the two plans under study (2012).

Observing some of the areas of that courtly architecture gave several hints that required us to update our information. We had already detected some clues that we wanted to confirm and it is surely more appropriate to obtain a deeper knowledge of the Palace prior to the survey. We are used to detecting different wall thicknesses or to look at the different types of cutouts of doors and windows with its construction details and thus realize the architectonic fractures and continuities, so it is very important to deeply know every detail of the building. Another way to search for the original Palace structure is by looking at some of the ceilings that are now interrupted and reconstituting those spaces, or trying to fit the tile panels from the time of D. Teodósio that are now being recovered – in its overall composition they should fit up with some of the main rooms.

With this kind of analysis of empirical surveillance, at the time of this communication it was already possible to propose a possible development of the palace over time. It was a primary projection, only reporting a possible volumetric evolution. We still have so much to learn, mainly concerning what D. Teodósio had to deal with when he decided to increase his family's residence and how he imposed an advanced form of architecture in a preexisting structure.

The Continuous Research

At this time, we have concluded the survey work but the investigation is ongoing. We continue to discuss the issues regarding the communication of the architectural research so that the Palace can be perceived not only by specialists in this fieldwork. It is important that this knowledge can be shared with the whole public.

We are looking for a virtual model that fits specifically in giving a physical and architectural context to the existence of the 6303 objects surveyed over 637 folios. The 3D models and plans that reconstruct the architectural spaces change our view about the past, both as researchers and as citizens. They also make it possible to be continuously questioning interpretative options, and redefining architectural hypothesis. There is an awareness of the fact that these virtual reconstructions change the standard tools used in teaching and learning about art and architectural history. They allow people to earn a visual consciousness that becomes more attractive and coherent than the interpretative variations that literature allows. It is clear for the researchers of the *D. Teodósio* research project that the purpose of these models should be to recover the measures, spaces, and architectural language of buildings (palaces, in this case), helping to reflect on the construction processes and materials that were applied, and clarifying their different stages of existence. Digital reconstructions are increasingly becoming one of the key resources of the research teams in the field of art and architectural history. One can say that, despite the advanced technology that already exists, in this kind of researches this is something that is still maturing. Renderings and movies demonstrate certain capabilities that are now being adopted and that make it inevitable to take up these tools as a part of its growing development.

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Illustrations

Fig. 1 Ana Lopes (author's photo), Palace of Vila Viçosa, Vila Viçosa, Portugal.

Fig. 2 Ana Lopes, Three-dimensional reconstruction of the Portuguese military settlement in Safi, done under the research project 'Portugal and southern Morocco: Contacts and Clashes between the XV and XVIII' [FCT PTDC/HAH/71027/2006], Morocco, 2010.

Fig. 3 Ana Lopes, Three-dimensional reconstruction of the Portuguese military settlement and urban occupation in Azemmour, done under the research project 'Portugal and southern Morocco: Contacts and Clashes between the XV and XVIII' [FCT PTDC/HAH/71027/2006], Morocco, 2009.

Fig. 4 Ana Lopes, Plan of the Portuguese military settlement in Ksar—Seghir (remaining ruins' survey) and zoom of the citadel's plan, done under the research project 'Cities and architectures of Portuguese origin in northern Morocco: Asilah and Alcacer Ceguer' [FCT / CNRST], Morocco, 2011.

Fig. 5 Ana Lopes, Drawing reconstitution of the bulwark excavated by the archaeologists recovering the moat section of the Portuguese castle in Azemmour, done under the research project 'Portugal and southern Morocco: Contacts and Clashes between the XV and XVIII' [FCT PTDC/HAH/71027/2006], Morocco, 2009.

Fig. 6 Ana Lopes and Nuno Senos, Drawing of the ground floor of the Palace of Vila Viçosa, obtained by vectorization of overlapped scans of the existing plans, done under the project 'All His Worldly Possessions. The patrimony of the 5th Duke of Bragança, *D. Teodósio I',* [PTDC/EAT-HAT/098461/2008], Portugal, 2012.

Fig. 7 Ana Lopes and Nuno Senos, Drawing of the noble floor of the Palace of Vila Viçosa, obtained by vectorization of overlapped scans of the existing plans, done under the project 'All

His Worldly Possessions. The patrimony of the 5th Duke of Bragança, *D. Teodósio I',* [PTDC/EAT-HAT/098461/2008], Vila Viçosa, Portugal, 2012.

Fig. 8 Ana Lopes and Nuno Senos, Drawing superimposing the two plans of the Palace under study, done under the project 'All His Worldly Possessions. The patrimony of the 5th Duke of Bragança, *D. Teodósio I',* [PTDC/EAT-HAT/098461/2008], Vila Viçosa, Portugal, 2012.

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1 The paper here presented concerns the first phase of works that I have been developing as a member of the research team of the project 'All His Worldly Possessions. The patrimony of the 5th Duke of Bragança, *D. Teodósio I'*, Centre of Overseas History (CHAM), *Faculdade das Ciências Sociais e Humanas*, *Universidade Nova de Lisboa* and the *Universidade dos Açores*, in collaboration with the Foundation of the House of Braganza (FCB), and financed by the *Fundação para a Ciência e Tecnologia* [PTDC/EAT-HAT/098461/2008]. The project is directed by Jessica Hallett (coord.), Nuno Senos (CHAM) and Maria de Jesus Monge (FCB).

2 The accepted submission I made to the European Scientific Foundation, for a short visit grant, made it possible for me to attend the workshop *Virtual Palaces, Part II*.

Visualizations of Rubens's Palazzos of the 17th Century in the Antwerp 'Nieuwstadt'

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Introduction

The *Visualizations of Rubens's Palazzos in the Antwerp 'Nieuwstadt'* is a report on several research projects, some finished, some still in progress, that have taken place over the last few years at the department of Design Sciences of the University College of Antwerp, which is now being integrated as a faculty into the University of Antwerp. A substantial part of this research was done by a former student architect Sigurd De Gruyter.

In this research project, we wish to examine Rubens's interest in the public space. An interesting thought is that he might have been thinking of the still nearly undeveloped area of the 'Nieuwstadt' (New Town), an extension of the medieval city in the north of Antwerp, just inside the new Spanish walls. We can begin to imagine how Rubens viewed a city extension by examining his *Palazzi di Genova* and applying its conclusions to this part of the city of Antwerp. The concept of the innovative Strada Nuova can theoretically be transferred to the large, long blocks of houses planned for the Nieuwstadt. The grid pattern appears to form a suitable basis for such a town-planning project, and this arrangement of streets is indeed found in the layout of the Nieuwstadt-project by the city architect Peter Frans.

Antwerp in its Golden Age

In the first part of the 16th century, the city of Antwerp was experiencing its first peak. At the height of its economic power with nearly 100,000 inhabitants (already 84,000 in 1540), it was the fourth of Europe's largest cities and became the most important economic centre in Europe. The growing pace of port activities and subsequent wealth meant that the 16th century may now be regarded as the 'Golden Age' of Antwerp. Northwest Europe assumed the position formerly held by the Mediterranean basin, and Antwerp took the lead over ports such as Genoa and Venice. The growing population necessitated the construction of a large number of new homes. Between

1496 and 1568 no fewer than 88 streets were laid out. The driving force behind these works was Gilbert Van Schoonbeke, a land speculator and building contractor.

Still confined within the boundaries of its medieval wall, the city was bursting at the seams. To the north as well as to the south of the city, there was a considerable amount of open land suitable for expansion (fig. 1). In the subsequent years both sides of the town were developed, in completely different styles, both in terms of economic purpose and layout. The North as a prosperous and efficient port extension according to the latest developments in urban planning, now called 'the grid', and the South as an extended defence system including a citadel.

Fig. 1 Antwerp seen from the west, anonymous copper engraving, ca 1525.

Fig. 2 Antwerp seen from the east, woodcut by Virgilius Bononiensis, 1565.

With Europe in political and religious turmoil, the city council, by order of the emperor Charles V, started the full renovation and expansion of the medieval wall into a bastioned defence system in 1542, to be compatible with the new ballistic developments of warfare. This wall, finished in 1553, would later be known as the Spanish walls and enclosed, to the north, an additional 25 acres that would become the Nieuwstadt (fig. 2).

Taking advantage of the city council's financially difficult situation in these turbulent times, the private entrepreneur Gilbert Van Schoonbeke persuaded the council, in exchange for his assistance with the construction of the fortifications, to be allowed to develop this ambitious Nieuwstadt with the aid of the city master builder Peter Frans, who had been active in the field for forty years. According to an inventory prepared by Adrian Bos in 1584, Peter Frans was responsible for at least fifty buildings, urban projects, infrastructure or military reinforcements in Antwerp.

In 1622, more than ten years after having returned to Antwerp from a professional and diplomatic visit to Italy, Peter Paul Rubens edited *Palazzi di Genova* (two books in one volume) (fig. 3). In this catalogue of Genoese palazzos, some erected in the Strada Nuova, the Strada Balbi and in the quarter of Sampierdarena, each building was depicted in full architectural detail. In fact, Rubens edited in folio the plans (ground plans, façades and cross sections) of 31 Genoese palaces and 4 churches, which were built between 1540 and 1620. Most of the buildings were seen by Rubens during his sojourns in Italy between 1604 and 1607. He collected about 137 drawings, some during his stay in Genoa and others were sent to him after he returned to Antwerp. 122 of those drawings survive, and belong to the collections of the Royal Institute of British Architects in London. The engraver was Nicolaes Ryckemans, employed in Rubens's studio. Rubens himself also added a number of corrections to the engravings. In his foreword to the first book, he brings attention to the interest those buildings have for the new architecture in the Low Countries. He wrote that he published these drawings of buildings because they are very useful and extremely comfortable for our citizens and noblemen. They are not so much characterised by the use of an inner courtyard, but by taking the form of a cube. Very remarkable is his preference of the Villa Cambiaso (1548) designed by the Roman architect Galeazzo Alessi (1512-1572). In this palazzo, the ground-floor plan is divided into nine rectangles, which are repeated on the second level. These types of houses are very compact and are also characterized by a *sala* (or *salone*) in the centre of the structure. The total structure of Alessi's city palaces is rational and simple and was a model for other palaces that Rubens saw in the Strada Nuova in Genoa. Another typical feature of the Genoese palaces is the use of mezzanine storeys between the main floors, for servant's quarters and service areas.

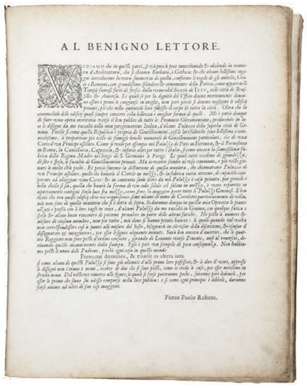

Fig. 3 Peter Paul Rubens, *Palazzi di Genova*, Book 1, Introduction to the reader, Antwerp 1622.

The reason for such a publication as Rubens's was to realize similar palaces in his own town by encouraging his wealthy clients to build their new homes according to the examples in the book. With the architectural profession at that time less developed than today, and open to great artistic input, these buildings would of course benefit Rubens as well as his business.

Unfortunately Van Schoonbeke failed in his project, and the city lost its economic wealth due to the successful blockade of the river Scheldt in 1585 and the Spanish occupation afterwards. As a result of the religious troubles and the start of the Eighty Years' War, most of the potential palazzo owners fled to the Netherlands. The city extension was never developed as foreseen, and no palazzos were ever built in that part of Antwerp.

The Project

Moments in history rich in drawings of ideas and imaginary projects do not arise by chance. Brief periods of powerful and radical changes in administration or domination by foreign powers appear to be the greatest stimulus to the urge to redesign the 'Metropolis', to use Antwerp's other, grander name. Although the realization of these proposals was limited, and was largely reversed after the surrender of Antwerp to the Spaniards in 1585, the intentions behind this planning operation survived until the 19th century.[1]

The historical background to this situation provides an ideal opportunity to explore, via a 'what if' scenario, the drastic reordering of the existing medieval town in a way that was obviously inspired by the then new architectural concepts of 'Commoditas' and 'Voluptas', developed by the Italian Renaissance.[2] The wealth of detail in Rubens's *Palazzi di Genova* publication, and the fact that the historical Genoese setting is still largely undisturbed, provided assurance that the necessary data would be available for evidence-based research raising this 'what if' digital construction to a higher level than a mere historical architectural rendering.

Goal of the Project

Beside the fact that 'what if' research is always intriguing and not uncommon in historical research, there is a special interest in this case from an architectural and digital perspective. At the department of Design Sciences of the Artesis University College the use of digital tools in historical architectural research is mostly oriented towards the understanding of a historical context and the validation of derived assumptions. In these projects, the mere visualization of the architectural buildings is secondary but obviously necessary. This project therefore falls in line with previous projects such as *'The Virtual City of Hans Vredeman de Vries Digitaly Analysed'* and *'Peter Frans, Master of the Masons Guild'*.

In order to construct (not reconstruct, as no palazzos were ever build in the Nieuwstadt) a virtual but valid historical urban project, it is necessary to study similarly built or planned projects. On the other hand, to create a virtual valid architectural construction, it is important to take into account, as is necessary in the real world, the limitations to construction, on both an environmental and social level. Implementing the latter process creates an insight and understanding of the task that, when projected onto the initial historical research, opens up a new perspective on the case and a better understanding of similar but completed buildings.

Course of the Project

The project followed a path of four distinct steps.

- Firstly, the historical research into 16th-century city planning and the development of the urban grid.
- Secondly, the implications of relocating the Genoese palazzos to this grid in the Nieuwstadt.
- Thirdly, the necessary adaptation of the Genoese palazzos due to the different environmental factors of the northern location of the city of Antwerp.
- Fourthly, the virtual construction of a set of these palazzos within the limitations of the case of the Nieuwstadt.

The New Urban Grid

The division of the Nieuwstadt into parcels by Peter Frans was influenced by some of the same principles as modern city planning developments now referred to as 'the Grid'. Designed in the years 1540s and 1550s, the Nieuwstadt revealed a plain grid of parallel and oblique streets with a geometrical checkerboard structure. It was the earliest 16th-century urban experiment in Antwerp that tried to solve the complex problems of urban planning on a large scale. The grid allowed for the creation of a new inner harbour by including three parallel canals, a series of quays for commercial purposes, the development of new commercial quarters with central warehouses such as the Hanza House, and the realisation of an underground water supply system to provide the new breweries with clean water in a comprehensive, but flexible way (fig. 4).

Gilbert van Schoonbeke was responsible for the implementation of Peter Frans's project. It was an extension of the city to the north together with the realization of one of the most spectacular fortifications in Europe at that time. Over a total length of about 6000 m, a new bastioned rampart, designed by the engineer Donato Bono di Pelizzuoli (? – 1555) from Bergamo, was achieved in about 15 years.

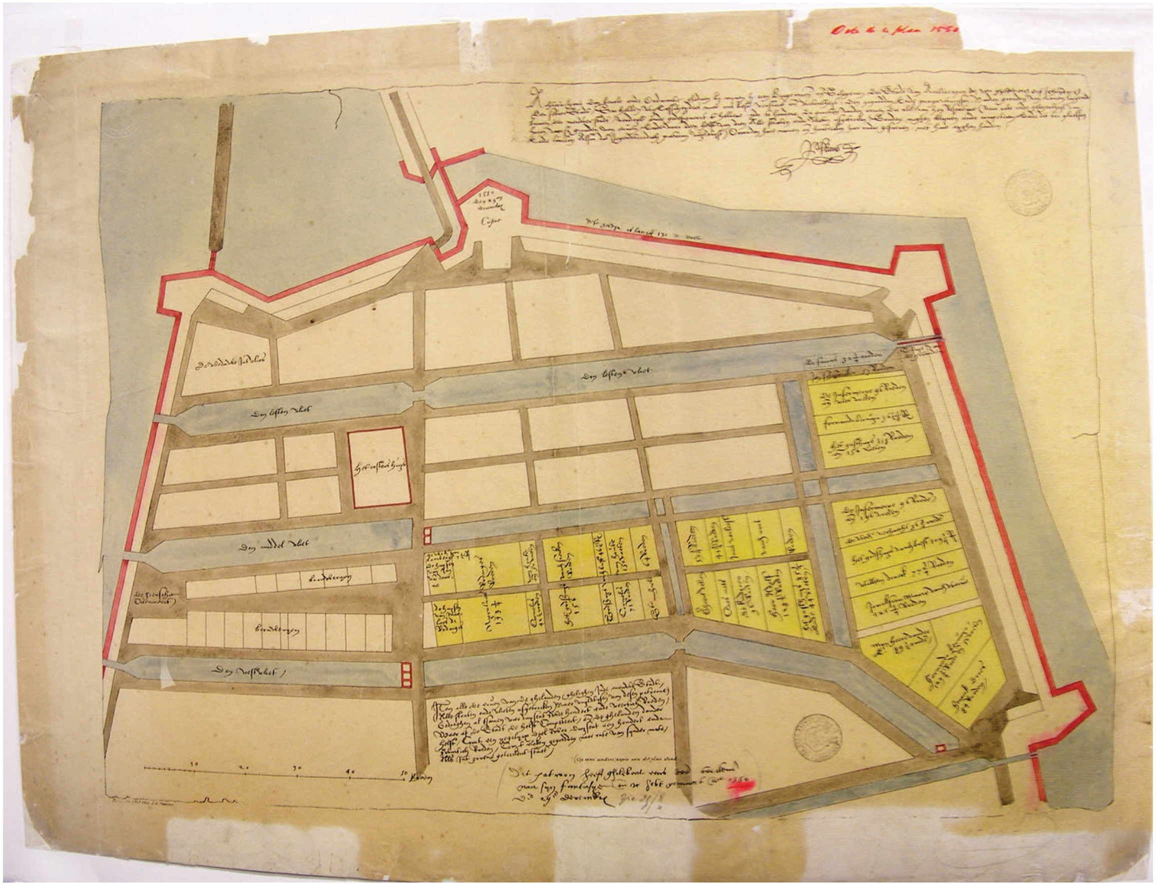

Fig. 4 Nieuwstadt, drawing by Peter Frans, ca 1550.

The *Castrametation of the Romans* by Polybius provides insight into how the blocks were further subdivided. This Roman historian of the second century BC designed a street plan of an ideal army camp, which was published in 1585 (reprint in 1592) in Godescaldus Stewechius's *Flavi Vegeti Renati, viri illustris De re militari libri quatuor* by the Plantin Press in Leyden. The model by Polybius comprises six parallel strips and two oblique strips. The grid model is not accentuated as such, but priority is given to the orthogonal street system. This street plan also inspired Sebastiano Serlio to propose his own project for a new city in his unpublished *Book on Castrametation* of the

Romans (fig. 5a). He transformed Polybius's castrametation into a walled city, paying special attention to the layout of the street blocks and their measurements. However, it is unlikely that Rubens saw this drawing and the text, due to its publication date.

Projects for city extensions that took place – or at least got as far as the planning stage – in the Northern Low Countries in the seventeenth century were examined to investigate what such a city extension could have looked like in Antwerp. One of the most interesting examples was the plan to develop a stretch of the Cingelgracht, an important canal in the city of Utrecht, as part of an urban expansion project drawn up in 1664 by Hugo Ruysch. The architect Antoni van Lobbrecht drew up a number of designs for this area in the periphery of the city (fig. 5b). The typology of the houses is very similar to the palazzos that Alessi drew for the Strada Nuova in Genoa. Their implantation along the canals is very regular and symmetric. It is certain that the Genoese palazzos were models of a new type of urban villas during the 17th century in the Northern and Southern Low Countries. These plans – preserved in both ground plan and vertical elevation – are indicative of the way in which the new harbour precinct of Antwerp's Nieuwstadt between the Brouwersvliet and the northern city walls might have been developed.

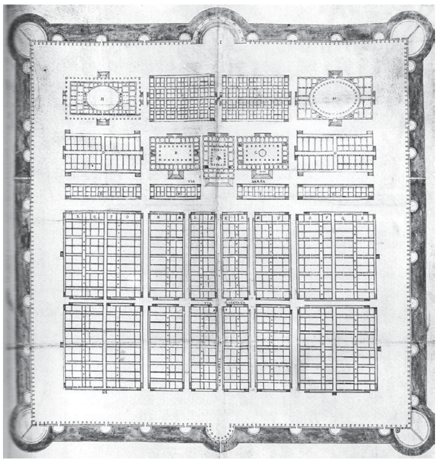

Fig. 5a Sebastiano Serlio: drawing of a 'citadella murata' or small walled city, from: S. Serlio, *Della Castrametatione* (1546-50).

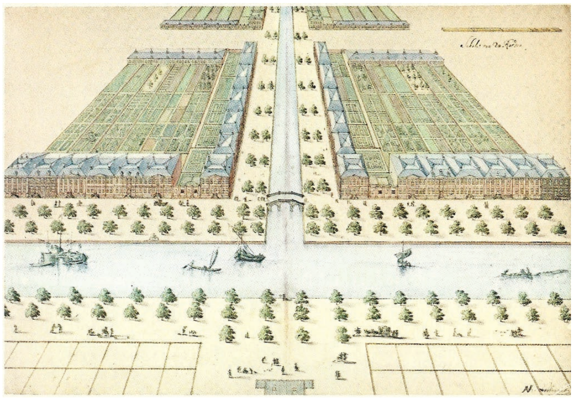

Fig. 5b Utrecht, 1664, drawing by Antoni van Lobbrecht.

The Relocation of Genoese Palazzos

It is tempting to just copy the concept of the innovative Strada Nuova from Genoa to Antwerp. Theoretically the concept could be transferred to the large, long blocks of houses planned for the Nieuwstadt according to the grid that was found in the design of Peter Frans. Van Lobbrecht's example, discussed above, already showed that compact town houses, with common walls and façades adhering to a strict vision, could display a harmony reminiscent of the Strada Nuova.

A digital relocation of the palazzos, even if only virtually, should at least take into account the environmental, social and constructional differences between the two locations in order to achieve a study object that allows valid analysis. The consequences arising from the environmental and social criteria will be discussed in further detail, but the differences in construction techniques require a preliminary observation. The biggest challenge would have been to compare the frequent elliptical vaults, which in the Genoese palazzos were always built in stone, whereas in the northern regions wooden vaults were common. This would imply the need to adapt stone construction to wood construction for all the major rooms. The examples of the Antwerp city hall in Italian Renaissance style (fig. 6a) and l'Hostel de Lyonne (Lyon), by Louis Le Vau (1660) (fig. 6b) show that there are several possible internal solutions which do not influence the interior of the buildings. It was therefore concluded that for this project it was not necessary to adapt the digital models to include specific construction techniques.

Fig. 6a Office of the Mayor in the Antwerp city hall (Jan Lampo – Hugo Maertens, 1993).

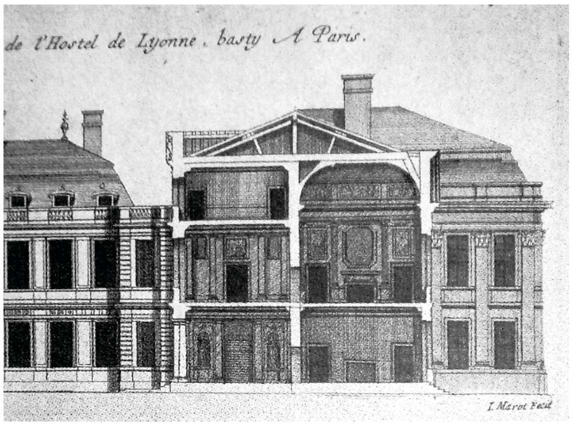

Fig. 6b Jean Marot, l'Hostel de Lyonne, by Louis Le Vau, 1660.

From 31 palazzos of several types that are illustrated in Rubens's two books, the palazzos A, B, D, E, F and G were selected. All those palaces are very compact, with no inner courtyard and considered very practical for cities of the size of Genoa and Antwerp. In this sense, Rubens was very aware of the resemblance of the large scale merchant cities of Genoa and Antwerp at that time.

It was of great assistance that Rubens has provided, for each of the houses, floor plans, façades and different cross sections, all dimensioned in detail (fig. 7). In Book I there are details of five different urban palaces situated in the Strada Nuova, two in other parts of the city and five in the quarter of Sampierdarena. The most innovative palaces were projected by the Roman architect Galeazzo Alessi. His palaces were very compact, with no inner courtyard (or only partly), a salone in mezzo, and a very regular ground plan with a grid structure of nine squares. The selected square palazzos, Rubens's favourites,[3] were duplicated in such a way that a total of 18 palazzos fitted into the structure of the empty building block of the Nieuwstadt without altering original dimensions.

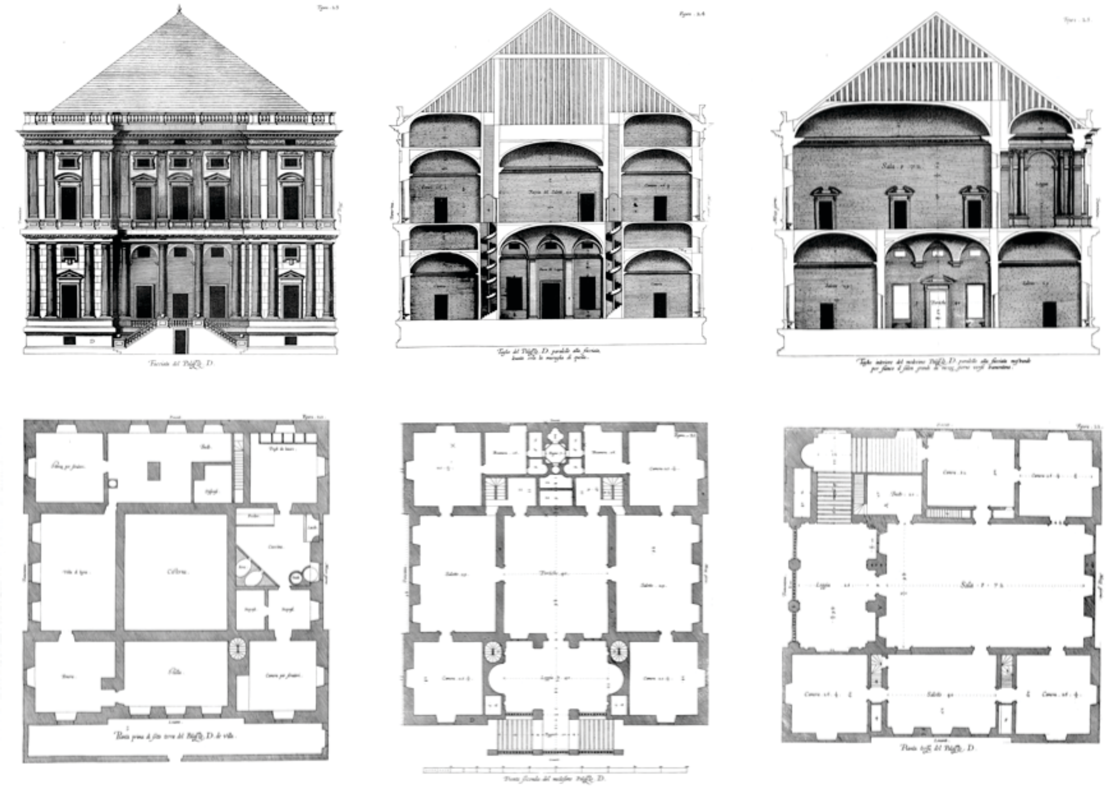

Fig.7 Façade, cross sections and floor plans of palazzo D, *Palazzi di Genova*, 1622, Peter Paul Rubens and Galeazzo Alessi.

The Adaptation of Genoese Palazzos

The different geographical locations of the city of Genoa and the city of Antwerp, the latter with latitude of 7° further north, would, on both environmental and urban level, require some adaptations to the palazzos in order to adapt them to the habitation conditions that the wealthy inhabitants of Antwerp were used to. On the urban level, the most radical alterations would have been the reorientation of the façades, the location of the gardens and the non-detached construction which results in the absence of side windows. On the environmental level, the different lighting conditions and, to a lesser extent, the temperature conditions were investigated.

Orientation of the Façade

It is very unlikely that Antwerp's rich inhabitants would have been content to have the façades of their houses turned away from the centre that is the origin of their wealth, i.e. the shipping activities taking place on the canals.

Location of the Gardens

Genoa is built on a hillside, were it is logical to have gardens in front of the house, oriented towards the bay, whereas Antwerp is flat and gardens are preferably protected by surroundings. Examples of such gated gardens can be found in Hans Vredeman de Vries's *Theatrum Vitae Humanae* (Antwerp, 1577), for instance in the engraving called *Childhood, or the Composite order* (fig. 16).

Terraced Construction

Due to the urban layout of the city of Genoa several small alleyways separate the palazzos in the Strada Nuova, and these function as important links within the city. According to the northern building style shown in Van Lobbrecht's example, the small alleyways between the Genoese palazzos were not applicable in Antwerp. It is however likely that over the total length of 267m (i.e. the length of the chosen building block of the Nieuwstadt), some intersections would have been appreciated. To determine passage widths, Sebastiano Serlio's Castrametation plan and the Peter Frans map were used. Based on the proportions of the primary and secondary streets in the plans, it was decided to include a transversal public street of 7m width and a longitudinal private walkway of 3m width. In figure 8, the layout of the Strada Nuova is projected onto the building block of the Nieuwstadt taking into account the above-mentioned alterations to better suit the Antwerp conditions.

Fig. 8 Left: Projection of the Strada Nuova on the Nieuwstadt building block. Right: The proposed layout adapted, with palazzos oriented towards the canals and enclosed gardens. (Both: AutoCAD™ 2009).

Lighting

In the Genoese setting, the palazzos were separated from each other by alleyways. Although they were relatively narrow, these alleyways allowed for the placement of windows on the side walls. Taking into account the depth of these palazzos (which sometimes extended as far as 30m) these windows were necessary to reach a working level of illumination in the central rooms. The Antwerp non-detached construction style results in a lack of windows in both side walls, and therefore we required a separate light analysis to determine the functional adaptations to be made to the palazzos.

The palazzo A, which is used as a representative for the other palazzos with respect to the light analysis, was digitally reconstructed using the AutoCAD Ecotect Light Analysis™ software. This allowed comparison of the light intensity, on the first and third floors, between the Genoese detached construction and the Antwerp terraced construction.

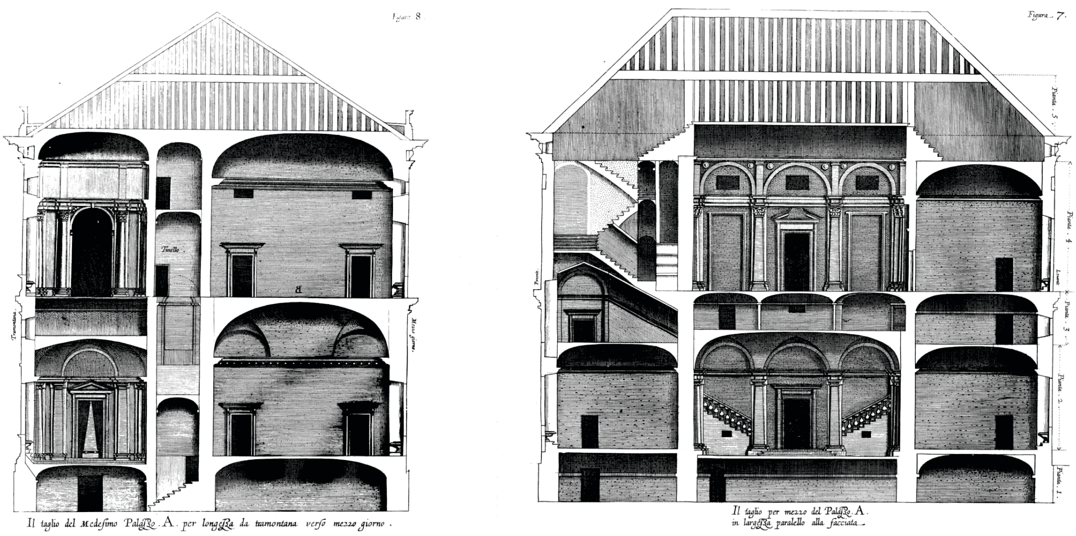

Fig. 9 Palazzo A, crosssection perpendicular to the façade (left), crosssection parallel to the façade (right); engravings by Nicolaes Ryckemans, 1622.

In the crosssections of palazzo A (Carrega-Cataldi), the centrally positioned portico and the salotto (loggia) is clearly seen on the first floor (pianta 2). The sala or salone is located on the third floor (pianta 4). Between the first and third floor there are several service areas, which in the Antwerp setting would prove to be problematic because of the missing windows. The primary focus of the investigation was on the most important living areas, located on the first and third floor.

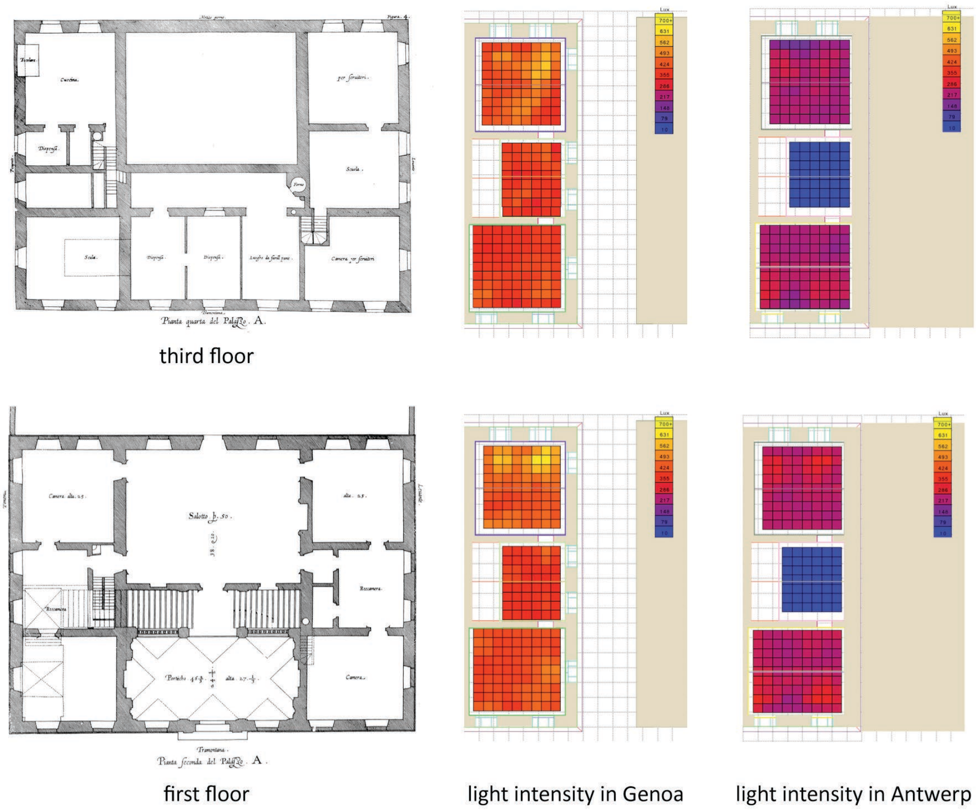

Fig. 10 Comparison of the difference in light intensity for the palazzo A between the Genoese detached construction and the Antwerp terraced construction (floor plans, engravings by Nicolaes Ryckemans, 1622; light simulations AutoCAD Ecotect Light Analysis™, 2009).

In the Genoa setting, 400 to 500 Lux was found in all rooms on the first and third floor. In the Antwerp setting, in the front and the back rooms a meagre 125 to 250 Lux was obtained, whereas in the central room the lighting conditions were truly problematic (fig. 10).

Serlio mentions in his books, that daylight in Italy is more intense than in the Netherlands, where it is more diffuse.[4] In fact, the average light intensity on a yearly basis is 5500 Lux in Genoa, compared to 4000 Lux in Antwerp.[5] This is a result of the difference in inclination of the sun above the horizon, namely 46° in Genoa and 39° in Antwerp. On the other hand, the lower inclination of the sunrays in Antwerp makes them penetrate deeper into the rooms than in Genoa. It is therefore not surprising that the relative window surface and their height–width ratio were remarkably different between the palazzos and the local Antwerp buildings of the time. Calculations on the façades of the selected Genoese palazzos and representative Antwerp buildings showed that on average the Antwerp window area was three to four times larger than the Genoese.[6] It is also a fact that the window height–width ratio in Antwerp decreases per floor (highest windows at ground floor) whereas the ratio in Genoa increases towards the top floor.

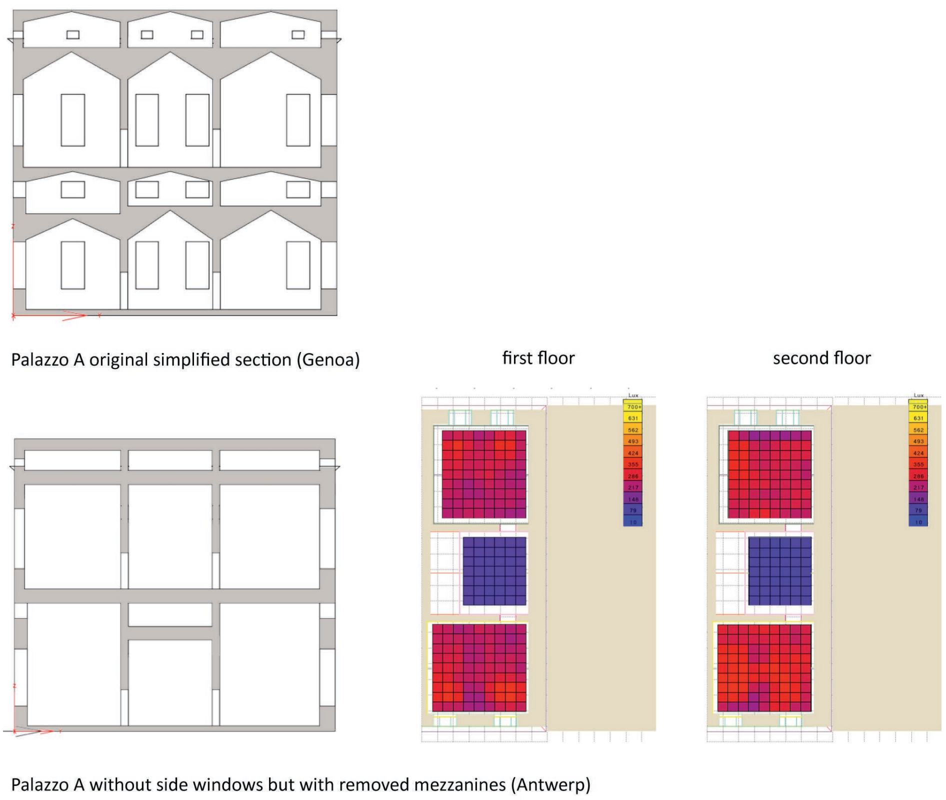

Fig. 11 Improved light intensity for the palazzo A, palazzo A with removed mezzanine (plans, engravings by Nicolaes Ryckemans, 1622; light simulations AutoCAD Ecotect Light Analysis™, 2009).

Given these conclusions, the same palazzo A was simulated after incorporation of the mezzanine area into the main rooms, but without alteration to the façade, i.e. retaining the mezzanine windows (fig. 11). The light analysis for the side rooms (where light conditions were most influenced by the lack of windows) showed a significant increase of light from 125 to 250 Lux, and up to 300 to 350 Lux in the front and back rooms on the first and the new second floor. Taking into account the less favourable indoor lighting conditions, to which people in the 16th century were used, it is considered that normal activities in these rooms were possible.[7] However, the light level in the middle rooms was still not sufficient. These spaces would therefore probably either be merged with the front or back rooms, or could be used for storage or activities that require low light levels.

In most of the palazzos depicted in Rubens's book, the staircases are either situated at the façade or at the rear, blocking the light to the central rooms. But the palazzo E and the twin palazzo by Giacomo Soluzzo and Battista Adorno show examples of a central staircase. The Trippenhuis in Amsterdam, which might have been inspired by this twin palazzo,[8] and which is well adapted to the northern lighting conditions, incorporates a central staircase.

Concerning the façades, no modifications were needed and it is interesting to note that the window ledges, extensively used in the palazzos, when situated beneath the window, in combination with the lower inclination of the sunrays, result in a better illumination of the adjacent room (fig. 12).

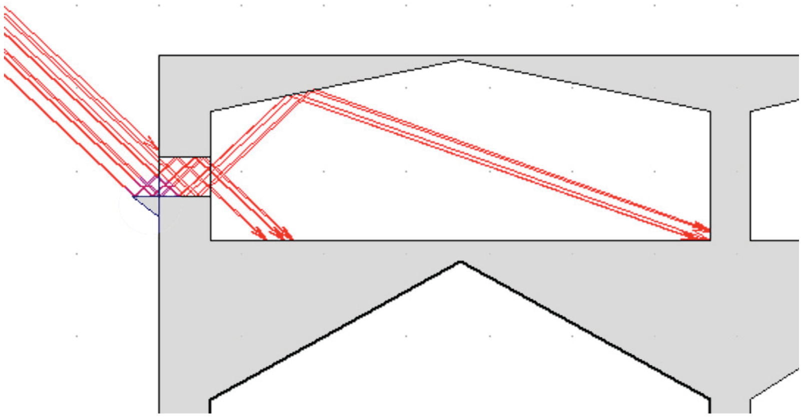

Fig.12 Incoming light reflected the window ledges increases the overall illumination of the room. (Plan and light rays simulation with AutoCAD Ecotect Light Analysis™, 2009).

Given the considerations discussed above, it is clear that relocation of Genoese palazzos to Antwerp would require a substantial, but not insurmountable, adaptation.

The Virtual Construction

Firstly, the building elements to be incorporated were defined or selected. These included an urban plan, a selection of about 6 palazzos, garden gates and ornamental elements, existing medieval and renaissance buildings and a schematic representation of the Spanish walls.

Cadastral Map

The original Peter Frans map and a plan from a later historical study were the basis for the urban plan executed in AutoCAD™ (fig. 13). With evidence of the first two blocks adjacent to the river already built, the block of choice was situated in the middle of the Nieuwstadt close to the former city development. As already mentioned, the success of this New City was very limited, due to the poor condition of the land, and above all, to the political instability of the Low Countries and especially of the city of Antwerp. The fall of Antwerp in 1585 was a real disaster for every further extension of the city. So, the plots and parcels of land remained undeveloped and were used by the citizens as gardens and for agricultural purposes.

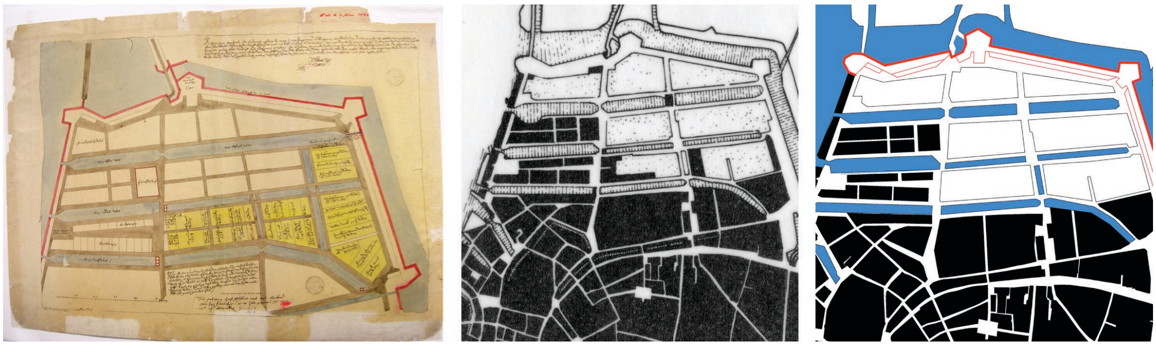

Fig. 13 Left to right: Peter Frans 1550, anonymous plan 1971, urban model in AutoCAD™ layout 2009.

Existing Buildings

The information relating to the development in the early years of the Antwerp Nieuwstadt is very limited. Three chronologically successive images, that were produced in the period 1557 to 1603, show with certainty late medieval buildings in the bock between the Brouwersvliet (brewer's canal) and the Middenvliet (central canal). Between the Middenvliet and the Timmersvliet (carpenters's canal) the Hansa House, which was completed in 1568, can be identified. In the other areas, there is inconsistent depiction of buildings, which may cast doubt on the accuracy of the images (fig. 14).

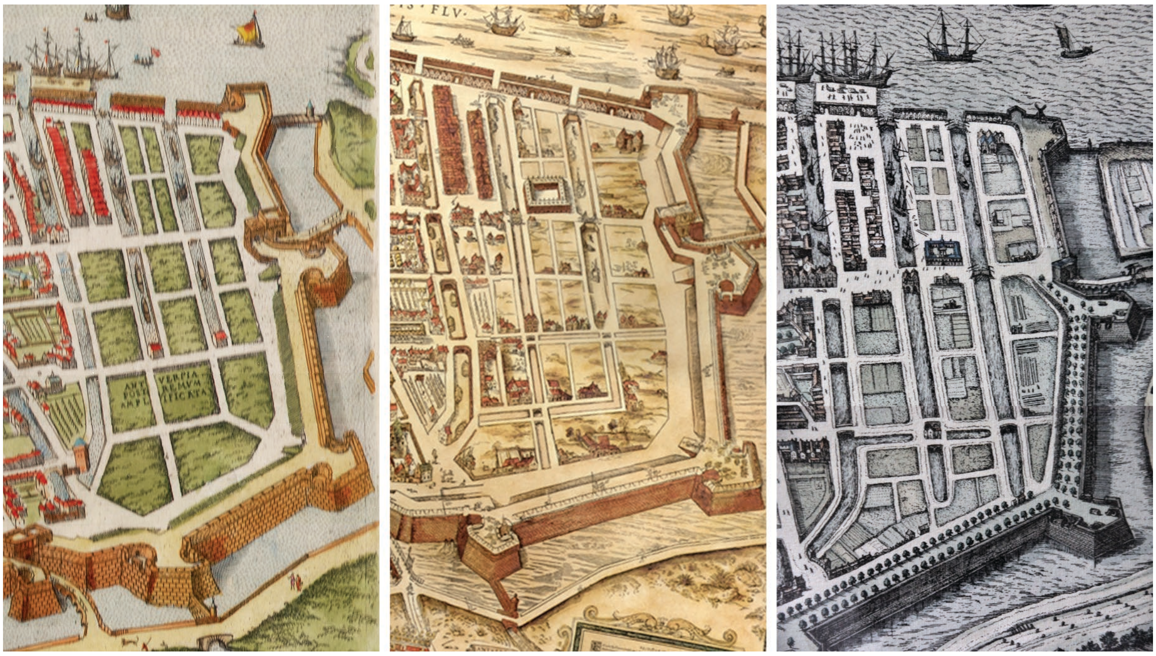

Fig. 14 Left to right: Claudio Duchetti, ca 1557 – Virgilius Bononiensis, 1565 – Joris Hoefnagel, 1598.

Palazzos

As it was not the intention to create a highly realistic and detailed rendered environment, the commonly available Google SketchUp 8 ™ software was used. The palazzos A, B, D, E, F and G were modelled, from the floor plans, elevations and façades available in Rubens's book and adapted where required (fig. 15). The 3D models, and the specific and dynamic sections that could be made in every plane, allowed us to study the light conditions in the succession of the rooms.

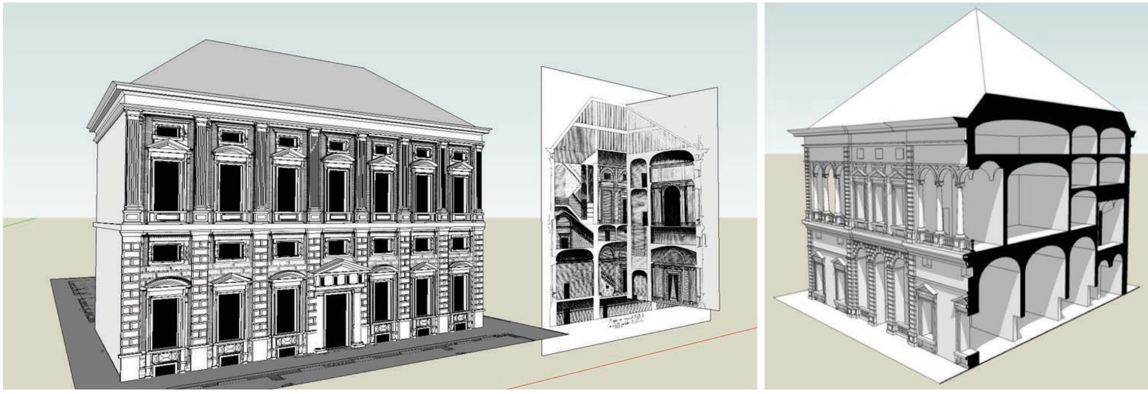

Fig. 15 Left: Palazzo A digital construction and corresponding drawings from Rubens's *Palazzi di Genova*. Right: Palazzo D, façade to back section showing the succession of rooms. (Palazzo A and D, Google SketchUp 8™, 2009).

Garden Gates

The reorientation of the buildings left the garden space and the transverse footpaths unprotected. Fortunately, well-documented works by Rubens's contemporary Hans Vredeman de Vries provide an example of how the garden space could be enclosed with a portico (fig. 16). This solution is very typical for the Renaissance gardens at that time, and offers the advantage of creating circulation patterns between houses and different parts of the gardens. Porticos can also be used as alternatives for the traditional brick walls between the parcels.

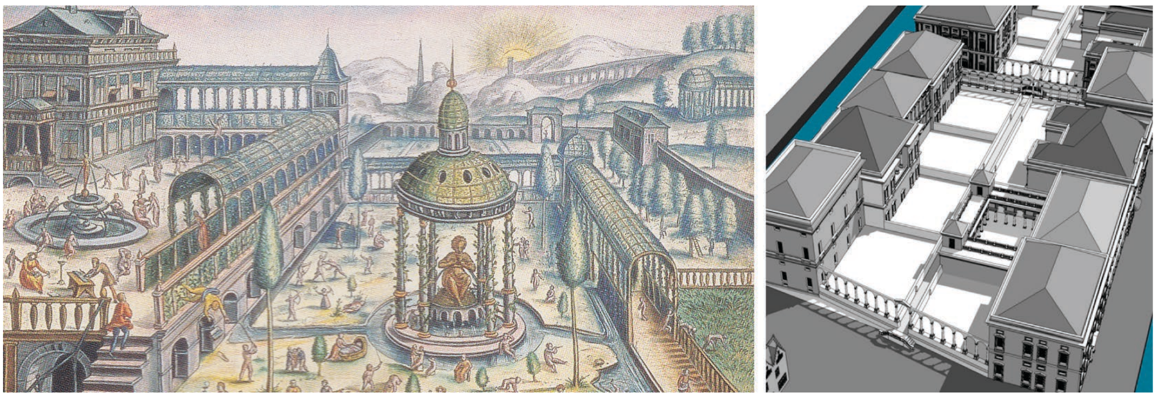

Fig. 16 Left: Gardens enclosed by porticos depicted in Hans Vredeman de Vries, 1577, *Theatrum Vitae Humanae,* Antwerp. Right: Inclusion of the porticos in the Google SketchUp 8™ 3D model, 2009.

Medieval Buildings

Although the medieval buildings were not the first concern, the fact that they are the only buildings on the site in large numbers meant that they had to be modelled to show their main characteristics in comparison with our subject. The terraced, gabled houses covered on average a width of between 3.44 m and 5.75 m and were up to 12 m deep.[9] Their construction and layout were straightforward, and in most cases determined by the adjacent buildings. Figure 17 shows a model of a typical Antwerp merchant house. The block between the Brouwersvliet and the Middenvliet (fig. 14) was filled with dense building, based on representative images of late medieval dwellings (fig. 18).

Fig. 17 Scale model of an Antwerp merchant house (1991).

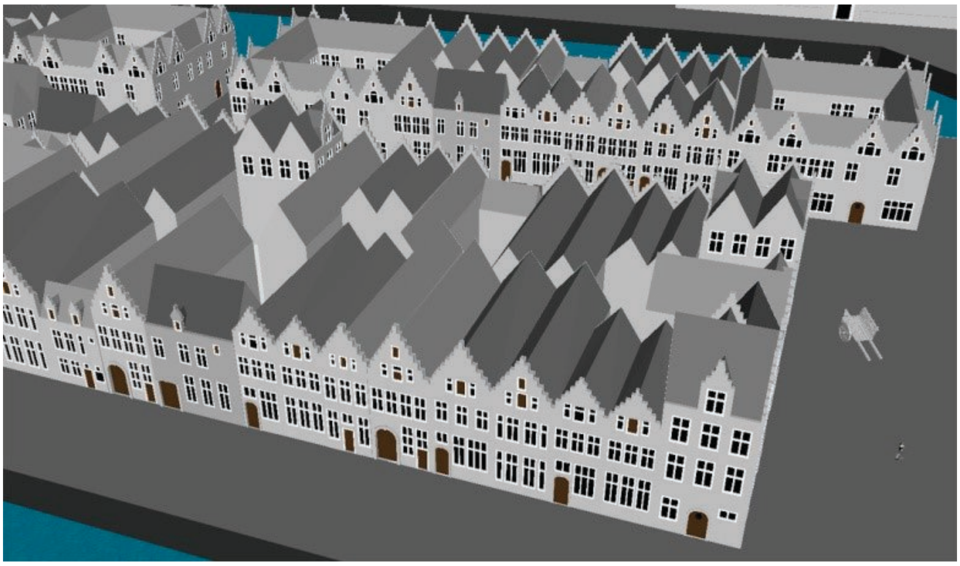

Fig. 18 3D simulation of medieval dwellings (Google SketchUp 8™, 2009).

Renaissance Buildings

The prosperity of the Antwerp merchants and craftsmen resulted in a demand for larger residences which became increasingly complex.[10] As some good images exist of the impressive renaissance Hanza House, actually built on the site, it is incorporated as one of the only authentic buildings in the visualisation (fig. 19). Other supporting buildings in the simulation were constructed according to images and descriptions by Hans Vredeman de Vries (fig. 20). The architect Hans Vredeman de Vries represented traditional scrolled gables in his drawings and prints. In his book *Architectura* (1577), he wrote that the condition of the parcels and streets in the Low Countries is such that the houses are small in length, deep and high.

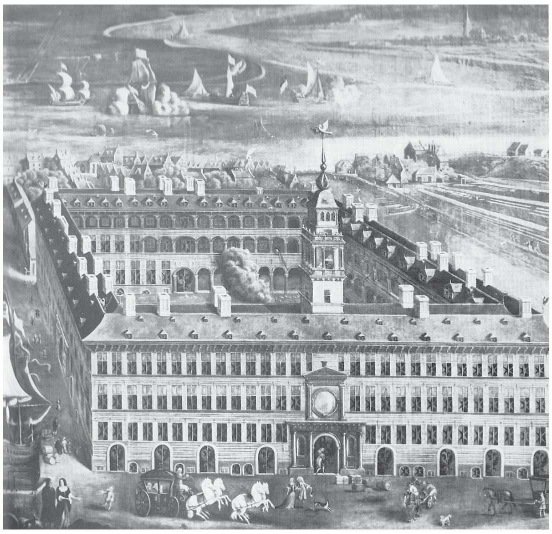

Fig. 19 The Hanza House, 18th century, artist unknown, Deutsche Marinemalerei.

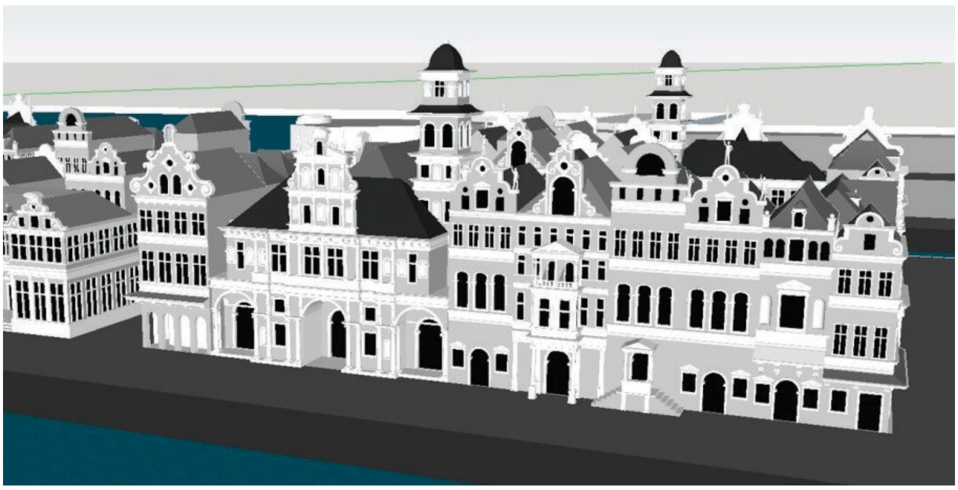

Fig. 20 3D reconstruction of buildings as depicted in Hans Vredeman de Vries's *Architectura* (Google SketchUp 8™, 2009).

Result

The result can be viewed as a series of perspective views of the Nieuwstadt filled with a Medieval quarter, a Renaissance quarter and the early Baroque Palazzo quarter which was the subject of the research. To provide a sense of setting from the perspective of residents, an animated walk-through was produced.

As mentioned earlier, the whole area of the Nieuwstadt was scarcely built upon in the aftermath of Antwerp's Golden Age (fig. 14). Nonetheless, there is good information on what the density of buildings in specific historical periods was. The image in figure 21 depicting the three quarters illustrates the striking difference between the visualised principles of the prevailing 16th-century Low Countries 'Medieval' buildings and the Italian, 'Renaissance' and 'early Baroque' approach. The figure shows, along the side of the late medieval city (bottom from left to right) the quay of the Brouwersvliet built up with a mix of medieval buildings. In the middle on the left side there is a densely built medieval quarter. This is the only area which was actually largely built, and includes a few remaining buildings. Above to the left, is the renaissance quarter, of which only the Hanza House was actually built. In the middle on the right, is the early baroque palazzo quarter. It is clear that such a neat segregation of building styles and ages is highly unrealistic. But with no palazzos ever built in Antwerp, there is no evidence of what a realistic mix might have been. It was decided, in the hypothetical context of the project, to keep the strict partitioning as this would enable a better demonstration of the differences (fig. 21).

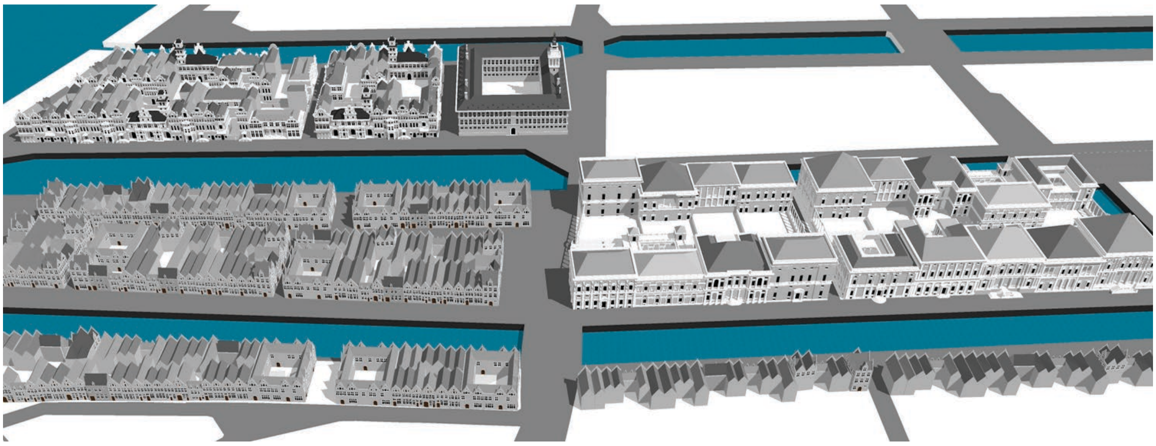

Fig. 21 Overview of the Antwerp Nieuwstadt depicting the medieval, renaissance and early baroque palazzos quarters (Google SketchUp 8™, 2009).

The images in fig. 22 and 23 show the palazzo quarter seen from the southwest (fig. 22) and from the east (fig. 23), both using a bird's eye perspective. In both images, the façade arrangements and the transversal footpath linking the gardens are depicted, enclosed at the ends by the Hans Vredeman de Vries porticos.

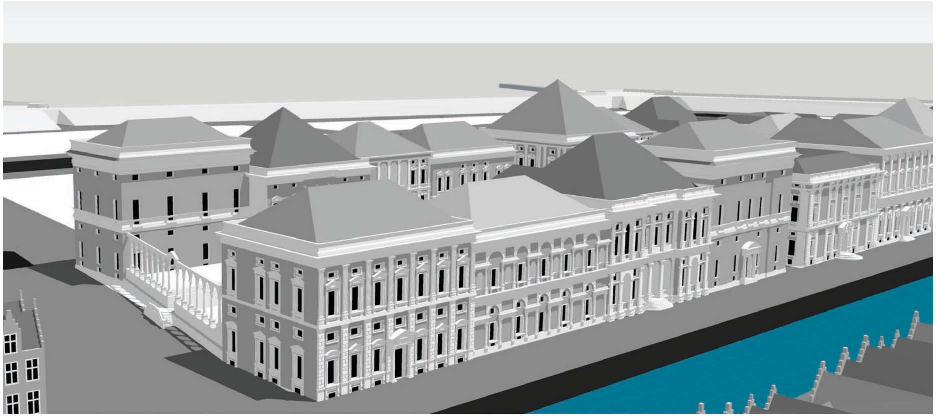

Fig. 22 Façade arrangement depicting in the front, from left to right, the palazzos A, H, E, Antonio Doria, (passage), I and F (Google SketchUp 8™, 2009).

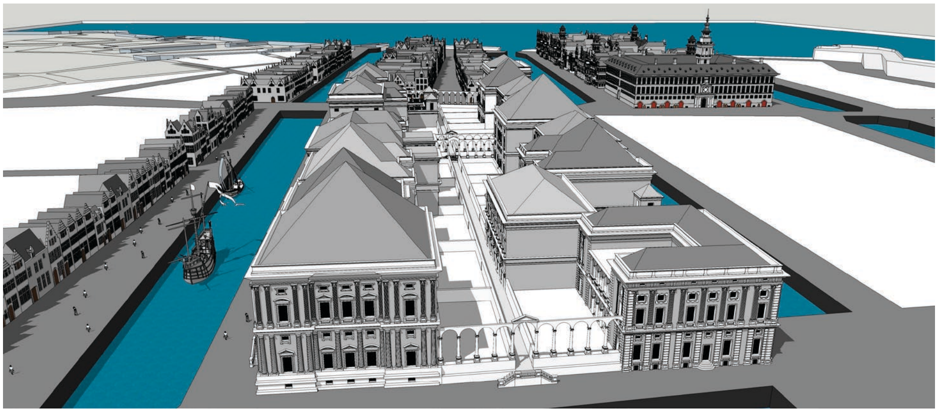

Fig. 23 Seen from the east, from left to right, the palazzo D, the Hans Vredeman de Vries Portico and palazzo I (Google SketchUp 8™, 2009).

Fig. 24 The Brouwersvliet viewed from eye level, showing medieval dwellings opposite palazzos (Google SketchUp 8™, 2009).

The images of the digitally constructed Antwerp Nieuwstadt illustrate, in respect to the palazzo quarter, a harmonious and unifying urban landscape. When considering:

- the connections between buildings;
- the similar heights of the roofs and the cornices;
- the well-structured inner gardens;
- the straight inner streets with access to both the outer streets and to the different back parts of the houses;
- and the openness of the building block,

it can be seen that, if a building programme based on palazzos would have taken place, it would certainly have radiated the image of Dignità and Grandezza – which are the two very important theoretical concepts of architecture and the arts that Rubens highlighted in his introduction to the book *Palazzi di Genova*, and which he found prevailing in the city palaces of the Strada Nuova and the Strada Balbi in Genoa.

Conclusions and Further Work

To draw conclusions from a study in which there are many unknowns, it is sometimes better to evaluate the methodology than the outcome. The approach taken in this project has clearly led to a result that is visually acceptable, and in accordance with historical examples. However, it should be noted that in this case several important environmental and urban factors were necessarily excluded. Recently, research has been started to examine 'the transformation of the city in the Low Countries', that will provide better insights into 16th- and 17th-century urban dynamics. This may eventually lead to a revision of the present study, with increased scientific substantiation and visual realism. This study has placed Rubens's Palazzos in the Antwerp Nieuwstadt, certainly a place they deserved to be in, but fate decided otherwise.

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Sources

Antwerp, City Archives, Inventory Peter Frans, prepared by Adrian Bos (SAA PK#2228 f26)

Illustrations

Fig. 1 Amsterdam, Rijksmuseum, Print Room.

Fig. 2, 14 (center), 14 (right) Antwerp, Museum Plantin-Moretus, Print Cabinet, World Heritage.

Fig. 3, 7, 9-10 Antwerp, library of the department of Design Sciences, historical collection.

Fig. 4, 13 (left) Antwerp, City Archives, SAA 12#4992.

Fig. 5a Antwerp, private collection.

Fig. 5b Utrecht, City Archives.

Fig. 6a-6b Antwerp, library of the department of Design Sciences.

Fig. 8, 13 (right) Projections, S. De Gruyter.

Fig. 10-11 Light simulation, AutoCAD Ecotect Light Analysis ™, S. De Gruyter.

Fig. 12 Rays analysis, AutoCAD Ecotect Light Analysis ™, S. De Gruyter.

Fig. 13 (center) Antwerp, library of the department of Design Sciences

Fig. 14 (left) Antwerp, City Archives, SAA 12#4109 and 12#4110.

Fig. 15, 16 (right), 18 3D digital reconstruction, Google SketchUp 8 ™, S. De Gruyter, 2009.

Fig. 16 (left) Lyon, Bibliothèque Municipale.

Fig. 17 *Stad in Vlaanderen: cultuur en maatschappij 1477-1787,* ed. Jan van der Stock (Brussels, 1991). Antwerp, library of the department of Design Sciences.

Fig. 19 Dresden, Deutsche Marinemalerei, 18th century.

Fig. 20-24 3D digital construction, Google SketchUp 8 ™, S. De Gruyter, 2009.

[1] Lombaerde 1990, p. 46.

[2] Ibid.

[3] Lombaerde 2002, pp. 64-66.

[4] Rosenfeld 1978, p. 56.

[5] Calculations carried out with www.nsesoftware.nl/wiki/maps.asp?params=51_13_17_N_4_23_50_E_type:city_region:BE&pagename=Antwerpen_(town) and params=44_025_00_N_8_056_00_E_zoom:13_region:it&pagename=Genua_(town).

[6] Calculations carried out by S. De Gruyter on five medieval dwellings in Antwerp in De Gruyter 2009, p. 28.

[7] For rough work, 125 to 250 lux is needed, but for normal work 250 to 500 lux is needed (www.kimbols.be/ogen/zien/verlichting.php).

[8] Lombaerde 2002, p. 92.

[9] De Naeyer 2008, p. 36.

[10] De Naeyer 2001, pp. 14-20.

City & Spectacle: A Vision of Lisbon Before the 1755 Great Earthquake

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Origins and Concept

City & Spectacle: a vision of pre-earthquake Lisbon consists of a virtual recreation of the city of Lisbon on the eve of the great earthquake of 1 November 1755, giving shape to a laboratory model for research into the city's history.

As its starting point the project has the virtual recreation of one the most emblematic of spaces from 18th century Lisbon, the Royal Opera House, which disappeared during the 1755 earthquake. The recreation of the Opera House was developed in the scope of the commemorations of the 250th anniversary of the 1755 catastrophe as an attempt to restore this space of the highest artistic quality to memory and to return it to the inventory of the Portuguese heritage of architectural history.[1]

Using Second Life® technology it was possible to put forward a model of both the structure and interiors of the Opera House as well as its animation combined with a small piece of the opera presented at the inauguration of the building in April 1755.

The public presentation of this virtual model at the conference *1755: Catástrofe, memória e arte* (1755: catastrophe, memory and art), which took place at the Centro de Estudos Comparatistas, Universidade de Lisboa, led to a debate on the study and critical analysis of documentary sources and their selection and application on recreations using virtual world technology. It also emphasized the need to extend the research on pre-earthquake Lisbon.

City & Spectacle: a vision of pre-earthquake Lisbon was thus devised as a recreation of the entire area altered by the rebuilding plan designed by the military engineers Eugénio dos Santos (1711-1760) and Carlos Mardel (1696-1763), which corresponded to the city centre and extended from the Castle Hill to the east, the Rossio square to the north, the Chiado area to the west and the Terreiro do Paço (Palace Courtyard) to the south (fig. 1).

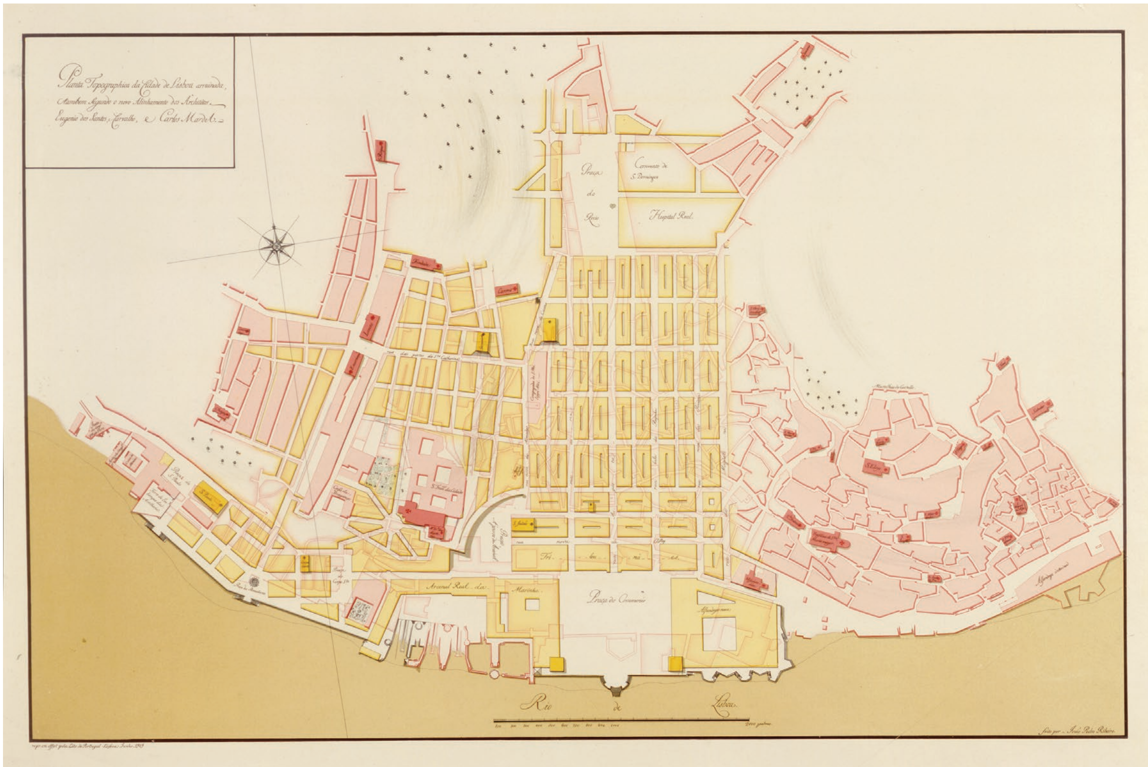

Fig. 1 Eugénio dos Santos and Carlos Mardel, adopted plan for the rebuilding of Lisbon (lithography), 1756.

However, cities are more than a collection of urban physical features. The architectonic fabric and the urban layout of pre-earthquake Lisbon were the framework of a living entity, with its own social and cultural characteristics. This reality was profoundly changed by the catastrophe and the rebuilding process. Therefore, the project quickly acquired a more comprehensive scope. The work, which is still in progress, will thus not only include the architectural and urban structure of the city, the interiors of some of the most noteworthy buildings, such as the Royal Palace, the Patriarchal Church, the Opera House, the Corpus Christi Convent and the All Saints Hospital, but also some of the most significant events of the time in Lisbon. Audio and animation components will be used to portray the social and cultural scenario of the city and text boxes will provide the historical context. The project therefore aims to recreate the spatial, architectural, social and cultural aspects of early 18th-century Lisbon.

The first phase of the project consisted of the recreation of the western side of Lisbon's Palace Courtyard just before it was destroyed by the 1755 earthquake. It includes the Royal Palace, the surviving part of the early-16th-century original palace, the Royal Opera House, the Royal Palace Garden, the Clock Tower, the Patriarchal Church and Square, as well as connecting streets. The aim was to integrate the Royal Opera House in the ensemble of buildings which developed from the Royal Palace and simultaneously propose a first recreation of the whole complex (fig.2).

Fig. 2 Aerial view of the Royal Palace complex
(photo of the virtual model, OpenSim version 0.7.5 Dev, 2012).

The first Lisbon public theatre, *Pátio das Arcas*, was also recreated according to its 17th-century layout (fig.3).

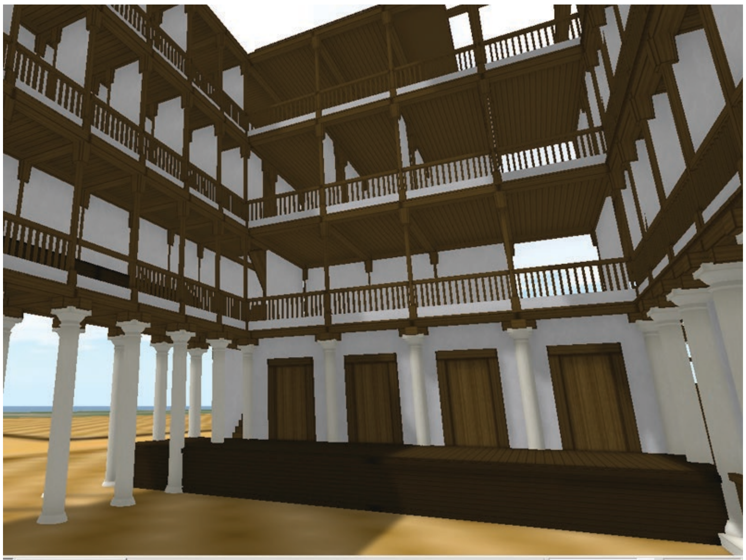

Fig. 3 *Pátio das Arcas*, the first Lisbon public theatre, in the 17th century
(photo of the virtual model, OpenSim version 0.7.5 Dev, 2012).

Innovative and experimental in its conception and methodology, this project can be considered as a laboratory in which virtual language is used as a means to broaden and optimise the scope of historic research. Based on a comprehensive study of urban phenomena from a historical and sociological perspective, it allows the results of a wide-ranging historiography of Lisbon to be tested in an interactive and immersive three-dimensional representation. Available online, the project will also contribute to the scientific debate and the sharing of documentary sources about the history of Lisbon and Urban History in the international context.

The project team includes researchers in the history of art, specializing in architectural history and town-planning, and experts in the creation of virtual realities and in the application of IT resources for research and the dissemination of history. The project benefits from the collaboration of Beta Technologies, which has worked with other virtual recreation projects in Second Life® technology, notably in the Theatron project of King's Visualisation Lab (King's College London).

Object of Study

Lisbon suffered the impact of one of the largest recorded earthquakes in history on 1 November 1755.[2] On the eve of the catastrophe, Lisbon was one of the most populated cities in Europe – the political and economic centre of an empire that extended from India to Brazil and a major seaport with a significant role in the maritime trading network of the period.[3]

Lisbon had been a highly cosmopolitan city since the early 16th century when the sea expedition to India in 1498 and the discovery of Brazil in 1500 had laid the foundations of the Portuguese overseas expansion. Nonetheless it had retained a mainly medieval, organic urban character. From the late 17th century, as a result of the initiatives of Kings D. Pedro II (1648 - 1706), D. João V (1689-1750) and the City Council with the providential help of Brazil's gold and diamonds, the city was undergoing efforts for its modernization and the changing of its image in the context of a Baroque and absolutist Europe.[4]

When the 1755 earthquake struck Lisbon, the City Council had exhausted its financial resources in trying to make the city more convenient and spacious. Concurrently, King D. João V had developed a vast programme of works in the main square of the city, the Palace Courtyard, and in the Royal Palace complex, following his aspirations to place Lisbon amongst the most prestigious capital cities in Europe.[5]

The Royal Palace was first built in the early 16th century by King D. Manuel I (1469-1521), who moved the royal residence from the Castle Hill to the riverfront. Surrounding the vast area in front of the palace, King D. Manuel I also erected a number of buildings directly linked to the management of the newly prosperous Portuguese maritime trade (fig. 4).[6] This area, the above-mentioned Palace Courtyard, became the most important square of the city, and the Royal Palace its most emblematic building.[7]

Fig. 4 Georg Braun and Frans Hogenberg, *Civitates Orbis Terrarum* (1598). Lisbon in the 16th century (engraving). At the centre of the image, the Palace Courtyard, the large square built as a result of the programme of works ordered by king D. Manuel I (1469-1521) in the context of the Portuguese maritime expansion. On the west side of the square, the new Royal Palace built on the riverside.

King Philip II of Spain (1527-1598), who ruled Portugal from 1581, used the skills of the architects Filippo Terzi (1520-1597) and Juan de Herrera (1530-1593) to carry out major renovation works in the Royal Palace.[8] These works consisted in the building of an imposing tower at the south end of the Palace and the closing of the gallery that shaped the original eastern façade (fig. 5).

Fig. 5 Dirk Stoop, the *Terreiro do Paço* (Palace Courtyard) in the 17th century (oil on canvas), 1662. This painting shows the Royal Palace after the renovation works ordered by King Philip II of Spain.

In the early 18th century, King D. João V renovated and extended the royal apartments, built a Clock Tower designed by the architect Antonio Canevari (1681-1764) and opened a new square, the first to be planned as an ensemble in Lisbon. This square was the location of the new Patriarchal Church, following the plans of Johann Friedrich Ludwig (1673-1752) (figs. 6, 7).[9] In April 1755, just six months before the great earthquake, King D. José I (1714-1777) added the Royal Opera House to the western side of the ensemble, according to the project of Giovanni Carlo Sicinio Gali Bibiena (1713-1760).[10]

Fig. 6 Francisco Zuzarte (attribution), the Palace Courtyard at the eve of the 1755 earthquake (china-ink etching), undated. Behind the Royal Palace are pictured the clock tower designed by the Italian architect Antonio Canevari and the Patriarchal bell tower designed by the German architect Johann Friedrich Ludwig. Both towers were built during the sovereignty of King D. João V (1707-1750) as part of a major renovation programme carried out in the Royal Palace.

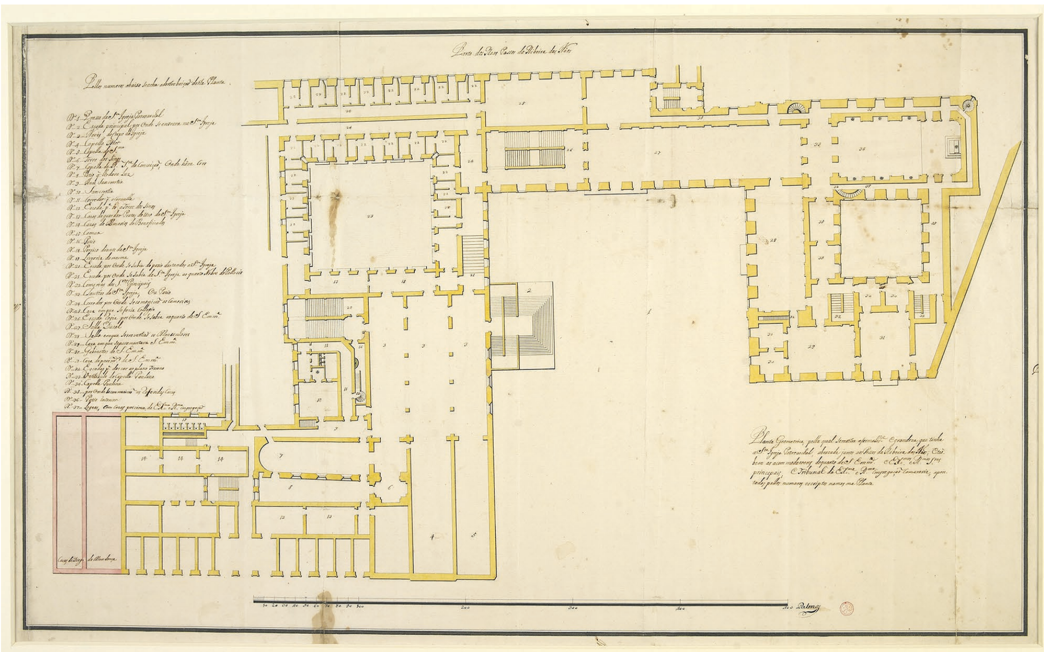

Fig. 7 Plan of the Patriarchal Church and Piazza.

On All Saints Day 1755, three strong seismic shocks, followed by a tsunami and a raging fire reduced most of the city to ruins.[11] According to contemporaneous accounts, approximately 10,000 to 15,000 people were killed in Lisbon alone; roughly 10% of the buildings were ruined and two thirds suffered such destruction that they were unsafe for habitation.[12] An important number of the city historical records, libraries, art and science collections, money and a large quantity of goods disappeared under the wreckage and were burnt by the fire.

The city centre, the large area between the two main city squares *Terreiro do Paço* (Palace Courtyard) and *Rossio*, was completely ruined. To the west, the riverside district of *S. Paulo* suffered the damaging effect of the seismic shocks and the tidal waves. The *Terreiro do Paço* disappeared under the rubble of the Royal Palace and all of the other important adjacent buildings, the Royal Opera House, the Patriarchal Church and square, the Custom House, the City Hall, the Tribunal and the newly built quay. The *Chiado* area, the hill to the west up to the gates of *Santa Catarina* location of the large convent of *S. Francisco*, was also severely damaged.[13]

The earthquake was also felt in other areas of Portugal and Spain, particularly in the south, and in North Africa. Several seismic events were reported all across Europe, from France to Britain, Germany and Finland, making the 1755 earthquake the first to be registered in detail and throughout such a wide geographical area.[14] The magnitude of the catastrophe shocked enlightened Europe.[15] The destruction of Lisbon made the headlines in the European press and inspired various texts of different kinds, notably Voltaire's *Candide ou l'Optimisme* (1759), and had a significant impact on European 18th-century thought.[16]

The 1755 earthquake provided the definitive opportunity for a large-scale rebuilding plan. After the catastrophe, Sebastião José de Carvalho e Melo (1699-1782), the minister to King D. José I and future Marquis of Pombal, with the essential assistance of Portuguese military engineers, built a city with a regular layout structured in uniform blocks (fig. 1). These quarters, known today as the Pombaline Lower Town, were built on the ruins of the old city centre. The rebuilding changed the image of the city irreversibly. The old Lisbon with its particular morphological and social characteristics disappeared.

Lisbon prior to the 1755 earthquake is a wide-ranging theme that incorporates distinct periods of history. As it refers to a lost city it has always aroused interest, but it is only in the last twenty years that it has been the target of systematic studies either in the fields of urban history, or in the areas of the history of architecture and town planning of the broader discipline of history of art.

The publication of the first detailed study that raised questions about the Pombaline project for Lisbon opened an important line of research on the urban phenomenon in Portugal and, more specifically, in the city of Lisbon, but now also seen from the history of art perspective.[17]

The analysis of Portuguese architecture from this period, particularly with regard to military architecture, as well as the skills of its technicians, notably that of the military architects and engineers, became a preferred context for the analysis of urban creation in Portugal and the Empire.[18] The first studies on Lisbon urban development using this kind of approach revealed that the Crown and Lisbon's City Council had developed a coherent strategy from at least the 16th century and had given military engineers extended powers and duties, thus explaining the speed and consistency of the Pombaline intervention after the earthquake. These studies also examine the close link that was established between these actions and the maturing of an idea of the city as a total organism, so that consistent dynamics of growth and modernization could be felt until the eve of the 1755 earthquake.[19]

The Lisbon of King João V belongs to this context of modernization of the city, and projects for urban land use and the city's facilities were put into practice and extended that originated from the previous reign. But what most identifies Baroque Lisbon is the building of the capital's new image as the stage for the representation of the Crown's political and ideological project. The articulation between the conceptual dimension of this urban strategy and its physical expression has been the focus of a number of studies, notably those from the 1990s.[20] The European contextualization of these dynamics of urban intervention has been the focus of emerging, albeit less frequent, research.[21]

This project will contribute to re-evaluating and furthering these lines of research, not only by the laboratorial dimension that the use of virtual worlds technology allows but also through the debate forum and exchange of information that it affords.

History and Virtual Worlds: a Laboratory of Research

Researchers and scholars of the history of Lisbon prior to the 1755 earthquake were always confronted with the same problem, the scarcity of documentary sources and the lack of urban and architectural remains significant enough to allow the verification of the information collected in the former. In fact, what was not destroyed by the earthquake, the tsunami and the ensuing fire, disappeared with the Pombaline reconstruction or was assimilated by it.

This situation resulted in a knowledge about pre-earthquake Lisbon, which has until now been contingent on a high degree of uncertainty, the relative abstraction of the narrative discourse, the two-dimensional aspect of the maps, drawings and engravings, and the social, economic and cultural background of their authors and the circumstances of their production.[22]

If we examine the documentary sources that were used as the basis for this phase of the project, the rebuilding of the Royal Palace complex, we will find that they are scarce and mostly pictorial material. These constraints make the research more dependent on literary sources and the rebuilding plans carried out after the earthquake. For instance, there is only a detailed description of the Royal Palace in the early 18th century, which reached us via a transcript published in a book by a renowned Portuguese author, Camilo Castelo Branco, in 1874.[23]

Fig. 8 Georg Balthasar Probst, *Vue du palais du roy de Portugal, à Lisbonne* (engraving), undated (ca 1730).

In relation to the iconographic sources, there is a clear predominance of the Palace Courtyard's depictions, in which the Royal Palace Tower built by King Philip II of Spain in 1584 acquires a prominent character structuring the whole perspective. The representations of the Royal Palace by Dirk Stoop dated from 1662, Georg Balthasar Probst dated circa 1730 and the china-ink drawing attributed to Francisco Zuzarte, dated circa 1750, are all examples of the above-mentioned assertion (figs. 5, 8, 6). For the north and west blocks of the Palace, inner-courts, interiors and other buildings of the complex the documentary sources are even scarcer.

With regard to the Opera House there is only a cross section of the building, which is controversial and a depiction by the French engraver Jacques-Philippe le Bas (1707-1783), which is part of a series on the ruins of Lisbon after the 1755 earthquake (fig. 9).

Fig. 9 MM. Paris et Pedegache and Jacques Ph. Le Bas, Royal Opera House (ruins), undated. *Colleçaõ de algumas ruinas de Lisboa causadas pelo terremoto e pelo fogo do primeiro de Novemb.ro do anno de 1755 debuxadas na mesma cidade por MM. Paris et Pedegache e abertas ao buril em Paris por Jac. Ph. Le Bas*.

The Patriarchal Church and Square, built by king D. João V between 1719 and 1749 after several building campaigns, are also portrayed in the series of engravings by Jacques-Philippe le Bas (fig. 10). There are also some descriptions of the Patriarchal Church interiors, as well a plan of the whole area kept at the National Library of Portugal (fig. 7).

Fig. 10 MM. Paris et Pedegache and Jacques Ph. Le Bas, Patriarchal Square (ruins), undated. *Colleçaõ de algumas ruinas de Lisboa causadas pelo terremoto e pelo fogo do primeiro de Novemb.ro do anno de 1755 debuxadas na mesma cidade por MM. Paris et Pedegache e abertas ao buril em Paris por Jac. Ph. Le Bas*.

Therefore, the documentary information, being rare and limited, should be cross-referenced with the most recent research on the urban layout and architectonic fabric of early-18th-century Lisbon, and compared with similar urban and architectural projects, signed by the referred to architects and engineers.

In order to achieve this central objective, the research team must, throughout the entire project, make a comprehensive and systematized survey of the manuscript, printed and iconographic sources related to the city of Lisbon, deposited in the repositories and documentary and bibliographic resources of archives and libraries. This process ought to be extended to the various exhibition catalogues and other publications about the 1755 earthquake and the history of Lisbon of the period. The aim is to gather not only the varied documentation scattered in different archives, libraries and museums, but also the contributions of the researchers on the subject.

In relation to the iconographic sources, this process is simplified by the selection of panoramas and landscapes of Lisbon or more detailed views, based in its accuracy and consistency. The selection needs to be more meticulous when it comes to the printed or manuscript documentation. A critical and comparative analysis of the documentation must be carried out so that the descriptions of Lisbon found in the written documents can be cross-referenced with each other and with the images. This will enable us to build a well substantiated picture of the city's urban layout, its architecture, the interiors of some of its most important buildings and the most relevant social events.

It is essential that a selection of the documentation collected and inventoried will be made available on the website that houses the progress of the project.[24] Not only will this give other researchers access to the information but also encourage contributions from outside the team as well as debate about the urban history and the specific area of the project itself at international level. The same spirit will dictate the inclusion of articles and other studies by the team members. The online availability of the primary and secondary sources conforms to the Principle 4 of the London Charter,[25] which states the need to document and disseminate the information used in the virtual recreations, in such a manner that the procedures applied and the results obtained can be understood by users and assessed in relation to the contexts and purposes for which they were developed. It also emphasizes the need to register all the analytical, deductive, interpretative and creative evaluation procedures performed in the construction of the virtual models.[26]

The sharing of criteria and assumptions between the project team and users allows the distinction of the different degrees of knowledge that shaped each element, thus differentiating a plausible recreation proposal from an exact reproduction of Lisbon in the first half of the 18th century. However, this approach seeks to overcome the contingencies of the crypto-history of art insofar as it goes beyond trying to describe the form of the work of art in question by giving a perception and understanding of its physical appearance and making it measurable (figs. 11, 12).

Fig. 11 Royal Palace, detail of the 16th-century surviving element
(photo of the virtual model, OpenSim version 0.7.5 Dev, 2013).

Fig. 12 Chapel Street – Royal Palace complex
(photo of the virtual model, OpenSim version 0.7.5 Dev, 2012).

The virtual recreation acquires a laboratorial scope by projecting the knowledge gathered about the history of Lisbon in a sensorial dimension through the use of Second Life® technology. This laboratorial dimension is apparent in the continuous process of critical analysis and testing of the written, iconographic and archaeological sources through the simulation of the urban setting, the buildings' exterior and interior designs, as well as the spatial, landscape and environmental context of the built environment. It is also present in the relationship between the scientific and technical teams. In fact, the recreation of the city ought to be undertaken by a transdisciplinary group of researchers, and the experts in virtual reality must be constantly accompanied by specialists in history of art so that the application of the information gathered is kept under permanent scrutiny (fig. 13).

Fig. 13 Patriarchal Church (photo of the virtual model, OpenSim version 0.7.5 Dev, 2013).

Several team members can simultaneously and interactively work online in the virtual world to create the architectonic and urban models. Each building can be validated by the research team as to its accuracy, using the documents and sources as guidelines, adjustments can be made and overseen as each element is brought to the virtual world and made to fit into the existing layout.

Virtual worlds are extensive networks that allow the construction of interactive and immersive virtual realities, highly credible virtual models and realities, at a low cost and without lengthy schedules. They also allow real-time interaction between technicians and users, and the free exploring of the built model by the latter, in a synchronous virtual environment through the use of avatars (a graphical representation of the user) (fig. 14).

Fig. 14 Royal Opera House (photo of the virtual model, OpenSim version 0.7.5 Dev, 2012).

Each user in Second Life® is represented by a virtual manifestation or avatar. Avatars are usually life-like and conform to human proportions. Thus, a chair is not simply a 'decorative element', but an item inside the virtual world which can be used by an avatar to actually sit down. This means some compromise must be reached between visual accuracy and detail and the ability to make many of the items on display actually usable by the avatars. This interactivity that can take place with objects in the platform allows solutions of augmented reality for didactic purposes. Therefore, users no longer have a purely contemplative perspective. They can freely explore the environment, interact with the model and share these experiences with others, in contrast with more rigid technologies that base themselves in pre-defined routes. These characteristics add a social dimension to virtual recreations. It is the possibility of interactivity between the users themselves that allows the featuring of guided tours for didactic purposes, or the creation of events for wider audiences.

There are countless academic and cultural entities currently using the Second Life® platform and its audience is estimated to be 17 million people worldwide, with a positive yearly growth of 20%. This evidence heightens the educational potential of this project and the innovative creative synergies that it is able to create.

The ability of constant updating of the model in real time and its immersive dimension conform to Principles 5 and 6 of the London Charter, reliability, sustainability and access. Principle 5 of the London Charter states the need to select sustainable and reliable computer-based visualisation in order to enhance the research outcomes and to extend its dissemination. Principle 6 refers to access and states that computer-based visualisations should be planned so as to ensure the greatest number of benefits in relation to the study, understanding, interpretation, preservation and management of Cultural Heritage.

We can thus affirm that Second Life® technology allows the proposition, discussion and updating of a virtual recreation, without the need for high budgetary resources and extended deadlines, directly promoting the scientific, didactic, and leisure character of the project and in correlation with its ample dissemination. It means we have overcome the plain formal and picturesque reconstruction from the beginnings of Virtual Archaeology.[27] A set of computer applications allowed for a three-dimensional viewing and realistic virtual representation of objects and buildings, which have already disappeared or suffered severe destruction, and thus had been very hard or impossible to interpret.[28] It was not yet possible to meet the goals of those who have worked the hardest to apply the new technologies to Cultural Heritage in order to make this tool not just an auxiliary technique, but an independent subject, with its own methodologies, techniques, and specific study goals.[29] However, it was possible to develop a computer epistemology applied to virtual historic recreations, seeking to study past phenomena, and providing a method for viewing ideas, organizing and summarizing facts, identifying, analyzing, understanding, representing, and transmitting the complex character of history, while more clearly presenting it in its many expressions: architecture, territory, or social context.[30]

Conclusion

In 1964, in his *Le Pensée Sauvage*, Claude Lévi-Strauss refers to a form of scientific thought that approaches the notions deriving from perception, imagination, and sensitive intuition, as the 'Science of the Concrete'.[31] It is in this 'Science of the Concrete' that we should therefore integrate art as a system of reasoning and symbolic representation of the world, as defined by the German historian, Hans Belting, when pondering the possible ending of the history of art. This is especially true, as this issue calls for the need to go beyond the boundaries between art and its social and cultural context, requiring different study tools, different interpretation goals, and an experiment-oriented approach, which is the only way to search for new answers.[32] The interactive and immersive dimensions that Second Life® technology conveys to the study of Lisbon prior to the great earthquake, reproduced by the *City and Spectacle* project, create a new scientific approach that we can consider analogue to the 'Science of the Concrete', by Lévi-Strauss, and that we may risk designating as the 'Science of the Virtual'. This 'Science of the Virtual' is also based on perception, and implies an experiment-oriented approach as well. However, in a time when the new technologies and the audio-visual means have altered our own concepts of reality and visibility, it does so through a simulacrum. By means of the ability to project a physical absence in the world (to represent it in space and time), of the sense that human conscience is capable of going beyond the body's physical boundaries, allows the cognitive, which can only be present in the intellectual sphere and that is only of the dominion of ideas, to be exposed to the sensitive sphere.[33] This means that just as in the case of the Renaissance's pictorial invention, which we call perspective, the technological creation of the virtual reality is a revolution of our way of viewing, since it suggests that we are seeing with our own eyes what we can only see represented – epitomizes the human vision renouncing the biological basis of that sense.[34] The transforming power of its impact over the production and transmission of historiographical knowledge, namely of urban history and architectural history, remains an open matter.

We can see that, after going from verbal to visual, and from analogical to digital, multimedia learning environments, mainly computer-based, are going from passive to interactive, giving computers the power to be the most important cognitive tool.[35] Technicians and researchers may also work simultaneously online, building, experimenting, and validating virtual re-creations, through a process that is similar to lab processes. We can actually say that the re-creation through virtual models of urban historical realities that have already ceased to exist or that have been deeply altered by the passage of time, not only allows researchers to visit past environments in real time, and to experience the effects of urban evolution, but also leads them to acquire a different perspective of the studied cities, particularly concerning the kinetic aspects of virtual historical environments. They may generate new knowledge since they require data and critical interpretations that differ from those required by narrative history, mainly structural and contextual information that relates in the same vision of the city aspects usually individually studied, such as architecture, population, movement, urban infrastructures, etc. Also unlike books and articles, virtual models and electronic databases are not static and, as we already mentioned, can be constantly updated and studied.[36] However, we do not think that books and articles are being replaced by virtual models, for right now they complement each other, since virtual worlds' technologies can be powerful problem solving tools, due to their ability to associate internal or mental representations with the external ones (objects, images, charts, videos, animation, etc.).[37]

Therefore, just as in the *Mnemosine Imagery Atlas* of Aby Warburg (1866-1829), the virtual pre-earthquake Lisbon is a notional place, where the history of art as a scientific field is subject to an ordained disorientation (the visitor may chose his/her own path), and becomes an almost non-verbal scientific domain.[38]

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Illustrations

Fig. 1 Eugénio dos Santos and Carlos Mardel, adopted plan for the rebuilding of Lisbon (lithography), 1756. Museu da Cidade (Lisbon City Museum).

Fig. 2-3, 12, 14 *City and Spectacle: a vision of pre-earthquake Lisbon*, OpenSim version 0.7.5 Dev, November 2012.

Fig. 4-6 Museu da Cidade (Lisbon City Museum).

Fig. 7-10 Biblioteca Nacional Portugal (Portuguese National Library).

Fig. 11, 13 *City and Spectacle: a vision of pre-earthquake Lisbon*, OpenSim version 0.7.5 Dev, September 2013.

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[1] This recreation was carried out under the supervision of Alexandra Câmara. See http://operadotejo.org/

[2] See Davison 1927; Davison 1936, pp. 27-28; Kendrick 1956.

[3] In 1700, the largest European cities (more than 100,000 inhabitants) were London, Amsterdam, Paris, Milan, Venice, Rome, Naples, Palermo, Madrid, Lisbon and Vienna. See Vries 1981, pp. 77-109.

[4] See Bottineau 1973; Pimentel 1988, II, pp. 685-710; Pimentel 1991; Ferrão 1994; Rossa 1998; Murteira 1999.

[5] See Pimentel 1988, II, pp. 685-710; Pimentel 1991, pp. 33-41; Rossa 2005; Martinho 2010.

[6] The building of the Royal Palace and adjacent administrative buildings near the riverfront is part of a wider programme designed to dignify the city and render it more functional. Developed by King D. Manuel I, it represents the first major attempt to change the strict organic layout of the city. See Carita 1999.

[7] See Senos 2002.

[8] The Union of the Portuguese and Spanish Crowns lasted until 1 December 1640, when the Portuguese Braganza family reclaimed the rights to the Portuguese Crown and proclaimed the independence from the Spanish Crown. This event was followed by a war between the two countries, which ended in 1668 when the Spanish Crown signed a peace agreement which formally ended the Iberian Union established in 1580.

[9] See Mandroux-França, 1989; Pimentel 1988, II, pp. 685-710; Pimentel 1991, pp. 33-41; Martinho 2010; Faria 2012.

[10] See Câmara 1996, 2006; Januário 2008.

[11] The 1755 earthquake is today attributed a magnitude of 8,75-9 on the Richter scale.

[12] Mendonça 1758. See also Ivo 1756; Castro 1763; Sousa 1919-1932.

[13] The vast survey of the destroyed city, ordered by Sebastião José de Carvalho e Melo (b.1699-d.1782), Secretary of State of the King D.José is the most valuable document of the extensive devastation caused by the earthquake to Lisbon. It is a thorough measurement of the city centre properties, also providing information about the extension and type of damage suffered by each one, the layout and name of all of the streets, alleys and squares of the areas destroyed by the earthquake. It is kept at the *Torre do Tombo* (National Archives) in Lisbon.

[14] See Davison 1936, pp. 27-28.

[15] The letters sent by the many British traders residing in Lisbon at the time to their families in Britain were published in various British newspapers giving a vivid and dramatic picture of the catastrophe. To this day, they represent the most expressive picture of the occurrence. See Nozes 1987.

[16] See Araújo 2007; Buescu 2005, 2006.

[17] França 1965.

[18] Moreira 1986, VIII, pp. 67-85; Moreira, VII, pp. 137-151; Correia 1991, 1997.

[19] Ferrão 1994; Rossa 1998; Murteira 1999; Carita 1999; Caetano 2004.

[20] Bottineau 1973; Mandroux, pp. 34-43; Pimentel 1988, II, pp. 685-710; Pimentel 1991, pp. 33-41; Câmara 1996; Câmara 2006, pp. 202-211; Rodrigues 2006; Januário 2008.

[21] Rossa 2005, pp. 161-186; Murteira 2004.

[22] Favro 1999, pp. 366-368. See also Boyer 1994 and Frugoni 1991.

[23] Branco 1874, pp. 10-11.

[24] http://lisbon-pre-1755-earthquake.org/

[25] London Charter. For the Computer-based Visualisation of Cultural Heritage. Version 2.1 February 2009, at http://www.londoncharter.org/downloads.html (accessed on 7 August 2012).

[26] London Charter. For the Computer-based Visualisation of Cultural Heritage. Version 2.1 February 2009, pp. 8-9 at http://www.londoncharter.org/downloads.html (accessed on 7 August 2012).

[27] Ryan 2001, p. 245.

[28] Grande 2011.

[29] See note 27.

[30] Ryan 2001 p. 246; Hermon 2008, p. 36; Grande 2011, f. 2.

[31] Lévi-Strauss 1962, p. 24.

[32] Belting 1987, pp. 29-33.

[33] Belting 2003, pp. 161-166; Stoichita 2011, pp. 9-11.

[34] Belting 2011, pp. 13-14.

[35] Rieber 1995, p. 54.

[36] Favro 1999, p. 370.

[37] Nechvatal 2001, pp. 417-418.

[38] Samain pp. 35-36.

Back to the Future

Visualizing the Planning and Building of the Dresden Zwinger from the 18th until the 19th Century

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In this article we[1] present a long-term project on the Dresden Zwinger (figs. 1, 2, 5, 6) using techniques that have been and still are very controversial – the production of imagery of architecture with the possibilities of computer programs. Since the very first thoughts on this topic, the technical requirements, possibilities and ideas about what can be achieved with the help of computer technique have changed dramatically. The question for which areas of application the computer could be necessary is still important today. With this project we want to present our approach in using computer technique for the virtual three-dimensional reconstruction of the history of the Dresden Zwinger.

Fig. 1 View of the Dresden Zwinger, specifically its buildings at the rear of the former fortification wall (photograph: first decade of 21st century).

Fig. 2 Arcaded gallery of the Dresden Zwinger along the fortification wall and moat, centered by a gateway tower, so-called Kronentor (photograph: first decade of 21st century).

Initiated in 2007 for museum-didactical purposes by the Saxon Administration of State-owned Castles and Gardens (Staatliche Schlösser, Burgen und Gärten Sachsen gGmbH) the project 'Back to the future – Visualizing the Planning and Building of the Dresden Zwinger' ('Zurück in die Zukunft – Die Visualisierung planungs- und baugeschichtlicher Aspekte des Dresdner Zwingers') led to a cooperation with the Dresden University of Applied Sciences (HTW – Hochschule für Wirtschaft und Technik) which reflects the working group's name 'Zwingerteam' in terms of a catch-word. The basic intention of this project is the mediation of the building development and the planning history of the Dresden Zwinger for the use in a permanent exhibition. That means that the easily recognizable form of a virtual three-dimensional representation of the complex range of construction activities will be used methodically and didactically as a way of teaching the architectural knowledge, and also as a help for the visitors to manage the mental transfer from the historic two-dimensional sources into the three-dimensional space. In order to produce an understandable survey the complex and lengthy building and planning development of the Zwinger has to be dispersed in a few well-selected phases, our so-called time-cuts. So, the situation is not an art-historical study of the architecture of the Dresden Zwinger, but a practical application with the following main objectives:

- to explain the construction development in its temporal sequence,
- to give an idea of selected complex range planning designs,
- to enforce an understanding of the Baroque system architecture, and
- to enforce a sense for architectural proportions, façade elements and spatial relationships.

Introduction

The Dresden Zwinger is the most famous Baroque building in the city with a diverse history and of art-historical importance. It started in 1709 under the reign of Augustus the Strong (at that time prince elector of Saxony and king of Poland) as an orangery laid out on one of the city's fortification walls at the rear of the Residential Castle (fig. 3),[2] and from 1711 this was extended due to the absolutist need for additional representative facilities (a planning example in fig. 4). In 1728 construction activities waned. From that year onwards the Zwinger buildings, meanwhile enclosing a courtyard at three sides, were used as a museum for the royal collections. Finally, in the midst of the 19th century, the gap on the north side was closed with the public picture gallery designed by Gottfried Semper (figs. 5, 6). In the mere consideration of that long term building development an extensive project grew out of an initially small task with increasing knowledge of the sources since 2007, such that in the end fourteen construction and planning phases of the Dresden Zwinger (as listed below in fig. 12) were virtually reconstructed respectively simulated in detail and fitted into a schematic topographic model of the closer surroundings (examples in figs. 7 and 10).

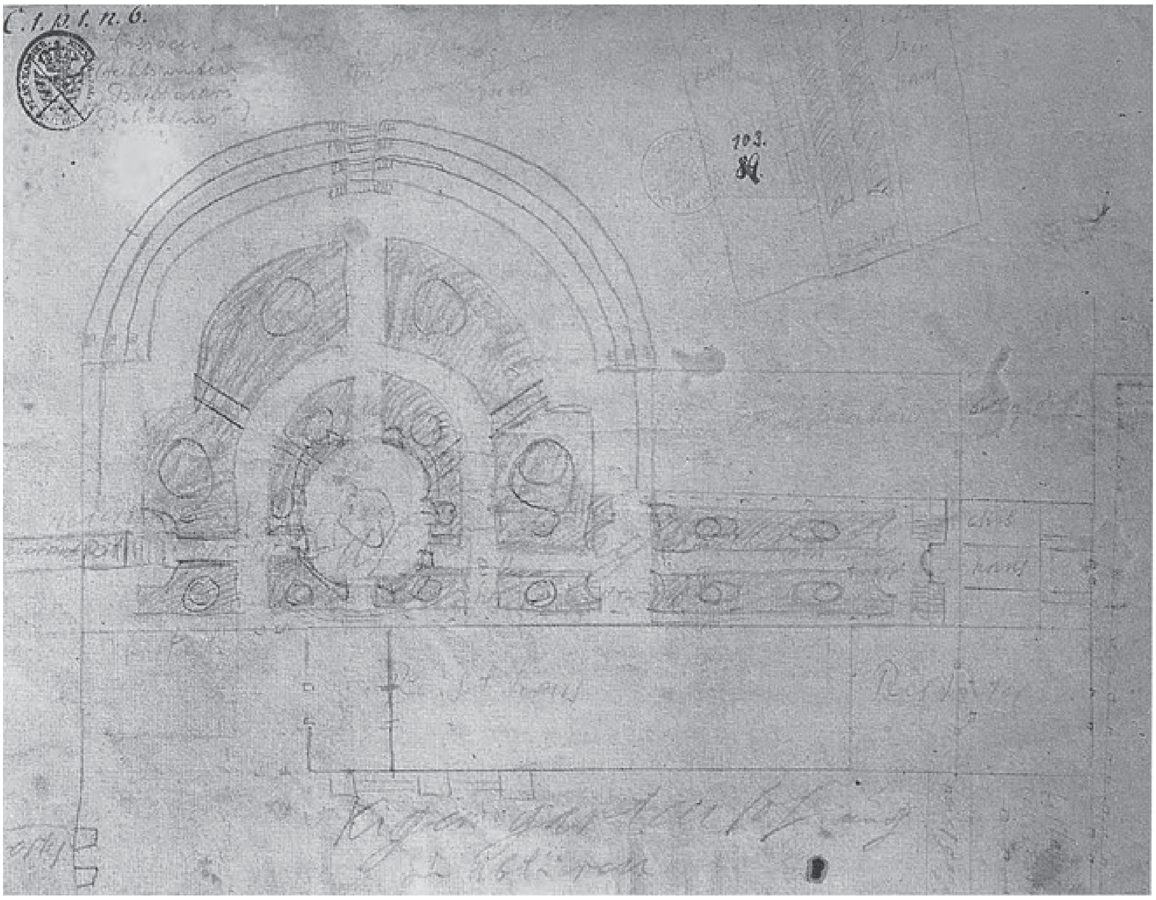

Fig. 3 Sketch by August the Strong from 1709 of an orangery laid out at the rear of the fortification wall beneath the residential castle of Dresden (so-called Zwinger area), used in the project as main source for time-cut no. 1.

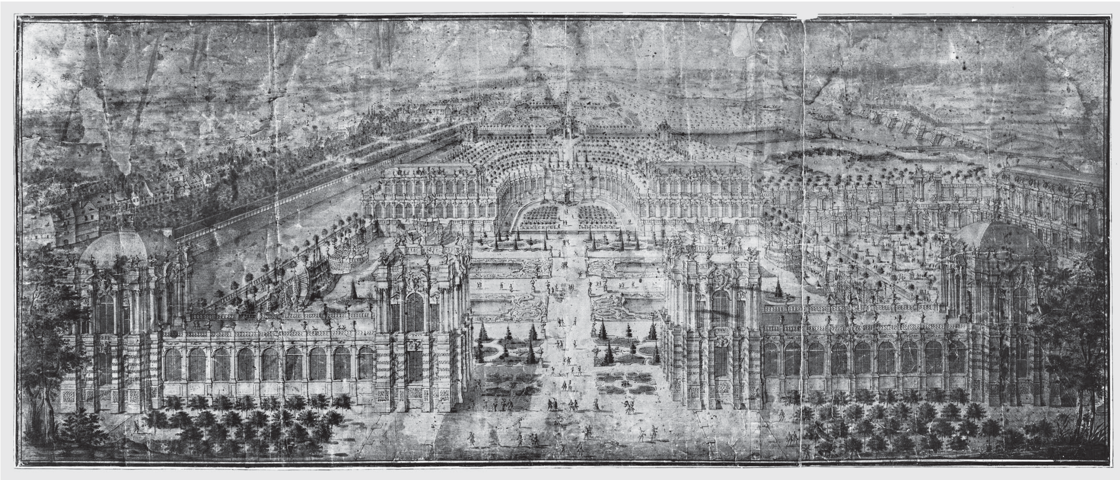

Fig. 4 Bird's eye view of an unexecuted Zwinger extension designed by Pöppelmann, 1712-13 (original lost since 1945), in the project used as main source for time-cut no. 3.

Fig. 5 Aerial view of the Dresden Zwinger: at the right the court church and the residential castle with the adjoined Taschenberg Palace is situated; above, between the Zwinger courtyard and the river Elbe, the 2nd court theatre, today known as 'Semper-Oper' (photograph: first decade of 21st century).

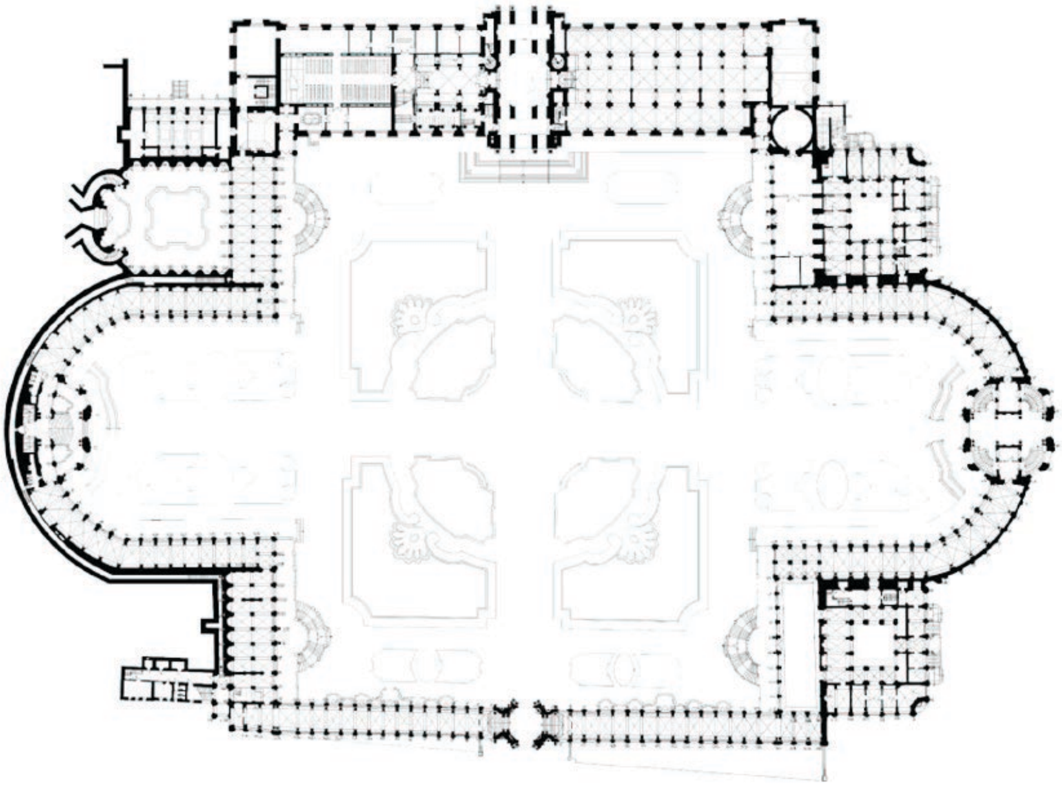

Fig. 6 Ground plan of the Dresden Zwinger from an architectural survey from 2008: on the left the initial Ω-shaped buildings at the rear of the fortification wall; on the right the mirrored buildings nearby the residential castle and the city; at the bottom the gallery aisle centered by the crowned gate; and at the top the picture museum added in the 19th century.

Focus of the Project

During a long processing time of more than five years the editing focus of the project has shifted considerably from the pure construction history towards favouring the ideal type of design planning. In these historic plans the Zwinger courtyard was not the sole subject of the draft, but rather part of a court complex that has always been connected with the residential castle, where it took the secondary role of an integrated garden (examples in figs. 4, 9). The expansion of such designs would range far into the contemporary urban space and would inevitably overlap them. The reflection of the models gives the future visitor the chance to find out where the planned buildings would have been located in case of their erection. This way they are able to get a keen sense of the dimensions based on their own physical experiences (figs. 7, 10).

Fig. 7 Virtual model of the building development in 1712-18 (time-cut no. 4), fitted into a schematic virtual model of the historic surroundings (modelling of buildings of the Zwinger in 2009-12, modelling of surroundings in 2011-12, merging of the individual models in 2013, rendering 2013).

In fact, this link between the built architecture of the Zwinger, its surroundings, and the historic unexecuted designs is also an added value for architectural research – namely, a verifying building simulation of unexecuted historic designs in combination with reconstructed building phases. Moreover, a review of the pure construction history of the Dresden Zwinger seems quite fragmentary considering the fact that many building activities must be regarded as a partial execution of more extensive designs. Since our efforts in preparing the three-dimensional reconstructions and simulations of buildings had evidenced that within the historic source material the discrepancies were more the rule than the exception, especially between ground plan and elevation, the critical harmonisation of differing sources turned out to be a special problem. A comparable problem was the question how gaps in the documentation could be filled in a convincing way. The experience made in the course of the modelling often led to a deeper understanding of a draft, and in the end to a critical and revising historical reflection on its structure, logic, quality and the possibility of realization. All these issues are of interest for the art-historical view on the Dresden Zwinger.

To present the project results within an exhibition we have taken into consideration the form of a teaching video for this purpose. The film will consist of the historical sources combined with the reconstruction of a fictional walk through the different states of the Zwinger building including adjacent areas of the town.[3]

Fig. 8 Virtual model of Pöppelmann's design for the Dresden Zwinger in 1722 (time-cut no. 8) in card board optic with part of the present Zwinger buildings and the residential castle in textured optic (modelling 2007).

The Sources

In order to achieve a valuable source library for the virtual models, our research consisted of assembling all visual source material which can give some evidence of the building and planning history of the Zwinger area. This material is very heterogeneously composed of plans, elevations, perspective views, and photographs (examples in figs. 9 and 12). To make all of it accessible for our project, the way of research led via the illustrations in relevant modern book publications into the archives and collections in Dresden which preserve the majority of the originals.[4]

The next step was a revision of the common opinions about the building and planning history of the Zwinger. The new reconstruction of Matthäus Daniel Pöppelmann's last vast garden project which has only been partially published in the so-called Zwingerstichwerk, Pöppelmann's own copperplate-publication of his architectural inventions, can be regarded as the most important result of this effort (figs. 9, 10).[5]

Fig. 9 Compiled sources for Pöppelmann's vast garden project of 1716–18, time-cut no. 5 (photo collage made in 2012 on the basis of situation plan and an elevation from ca 1715, copperplate prints from 1729, two new photographs from ca 2008/10).

Fig. 10 Virtual model of time-cut no. 5 (cf. fig. 9) fitted into an adequate schematic 3D model of the surroundings (modelling of buildings of the Zwinger in 2009-11, modelling of surroundings in 2011-12, merging of the individual models in 2013, rendering 2013).

In the end, fourteen so-called time-cuts were distilled from the visual sources (figs. 11, 12). They represent important building phases or design states. Our selection criteria have been the following: Primarily, the main building phases should be represented. Accordingly those five time-cuts (nos. 2, 4, 7, 12 and 14) are dedicated to the real building development of the area. From the more than 34 known projects which have remained unexecuted, we subjectively selected the eight most attractive and precious ones with respect to their urbanistic importance as well as their impressiveness. For pragmatic reasons we decided to model only those planning phases which are documented sufficiently by ground plans and elevations or which could be reconstructed without any further problems (discussion below). We also decided to represent all architects who were involved in the planning of the Zwinger area, beginning with Pöppelmann and ending with Gottfried Semper including Zacharias Longuelune, Jean De Bodt and Gaetano Chiaveri.

Fig. 11 Overview of the chosen 14-time-cuts mirroring the development of the Dresden Zwinger, each represented by one characteristic source.

1. Prince elector August the Strong 1709-10: sketched first idea (project)

Matthäus Daniel Pöppelmann:

2. 1711-13: Orangery at the back side of the fortification wall (building phase)
3. 1712-13: Extension of the orangery with garden and festivity areas (project)
4. 1713-18: Extension of the orangery with a central pavilion ('Wallpavillon') and a towered gateway ('Kronentor') between galleries (building phase)
5. 1716: Extension of the orangery with a water theatre and an enclosed garden (project)
6. 1716-18: Integration of the orangery in a vast new residential castle (project)
7. 1719: Mirroring of the orangery for obtaining a festivity yard and closing of the latter with an ephemeral stand (building phase; the last main one of the Baroque era)
8. 1722: Extension of the festivity yard with museum halls and a central pavilion (project)

Followers of Pöppelmann:

9. Zacharias Longuelune 1728: Extension of the Zwinger courtyard with a new residential castle (project)
10. Jean De Bodt 1736-37: Extension of the Zwinger courtyard with a new residential castle (project)
11. Gaetano Chiaveri 1746-47: Extension of the Zwinger courtyard with a new residential castle (project)
12. Anonymus before 1800: Provisory closing of the Zwinger courtyard with an arcaded wall (building phase; the wall was substituted for a new one and finally since 1847 for the picture gallery)

19th Century: Gottfried Semper:

13. 1842: Extension of the Baroque Zwinger courtyard into a forum with picture gallery and court theatre (project)
14. 1847-69: Closing of the Baroque Zwinger courtyard with a picture gallery in addition of the already erected court theatre (building phase; the theatre was destroyed 1869 by fire)

Fig. 12 List of the 14 chosen time-cuts mirroring the development of the Dresden Zwinger with date and main architect.

As a last step, the collected visual sources for the chosen fourteen time-cuts were digitized, uploaded and organized into a database to which the whole team had online access (fig. 13; http://www2.htw-dresden.de/~zwinger/, last accessed on 09.07.2015).

Fig. 13 Web-based database and project page at http://www2.htw-dresden.de/~zwinger/ (last accessed on 09.07.2015).

Modelling

In order to produce the virtual models in the computer, students of the HTW Dresden were recruited from the Media Computer Science degree program. In total 27 students have participated in the project to model the different time-cuts.[6] We started with the modelling tool 3D Studio Max 7, upgraded almost every year to a new version (fig. 14) which imposed a considerable amount of conversion work (last version: 3D Studio Max 2014). Moreover we also integrated the outstanding expertise of some members of the group with other modelling tools like Cinema 4D and Blender (cf. fig. 18 right) for which we had to find an exchange format and also an exchange workflow (at the end the file format 'obj' and adaption by hand worked best). Moreover the changing and replacement of team members (which we called 'student generations') were a big issue in our team which was tackled by intensive meeting and integration phases.

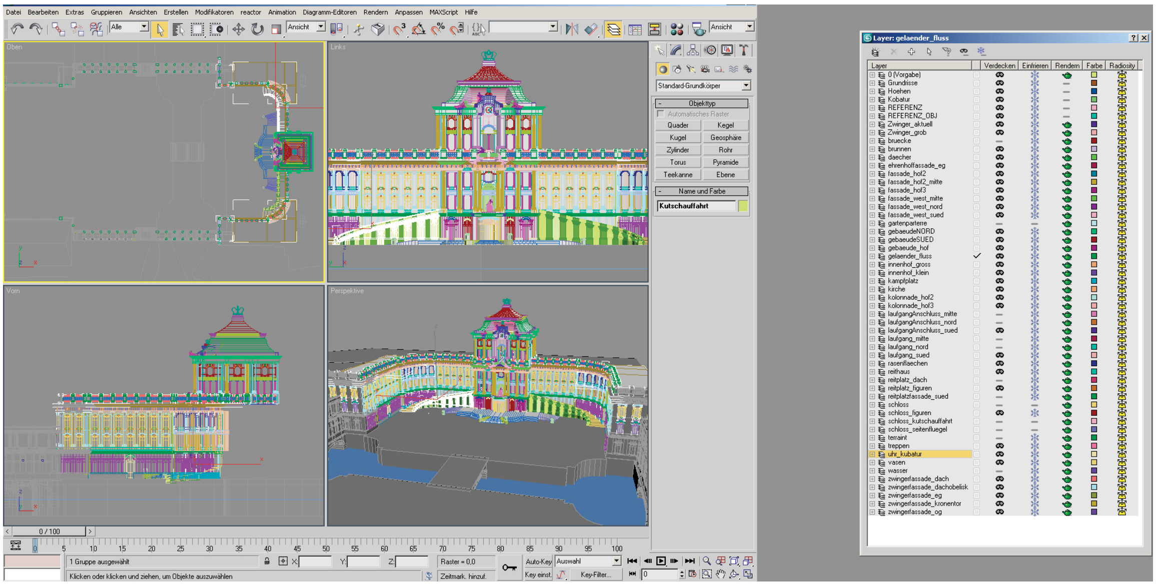

Fig. 14 Virtual model of time-cut no. 6 uploaded in the modelling software Autodesk 3D Studio Max 9 (model from 2010-11, screenshot from 2012).

Regarding the creation of the models, an immense amount of hand work has to be done to achieve the present state of each model, accompanied by intensive inspection and revision meetings (discussed below). Nevertheless some basic key modelling steps are presented next in order to give an idea of the modelling work. Here we concentrate on two main techniques: the box modelling and the spline modelling. Both start with orthogonal projected representations of the desired building such as the ground and elevation plan. But before that, as preparation, the information content of the compiled sources had to be sorted for assigning the elevations to a ground plan. Special diagrams of those correlations had been arranged for each time-cut to give the modellers a kind of guide line. The one shown in figure 15, prepared for the modelling of time-cut no. 11, i.e. the castle designed by Gaetano Chiaveri, exemplifies in another aspect also a sufficient supply of source material. The dealing of more problematic cases for the reconstruction, in which sources have been lacking, will be discussed below.

Before explaining the two modelling techniques, it must be pointed out that the 'Back to the Future' project focuses only on the cubic structure and the façades of the buildings, while their internal structure is not modelled.[7] The formal execution of architectonic elements varies depending on the specific quality and availability of the source material between the different time-cuts. Within a time-cut, however, a homogeneous level of detail has been pursued. The gradation of abstraction results from a steady and regular simplification of forms. In the course of abstraction considerable attention is paid to the compliance with the architectonic system.

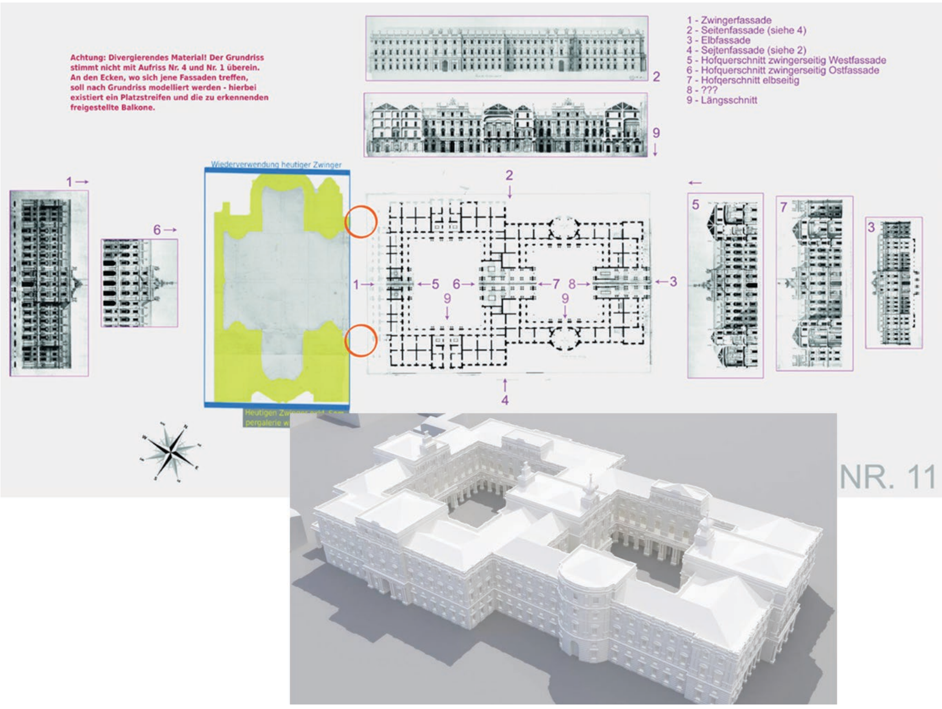

Fig. 15 Diagram (2008) of the correlating source material (ground plan and elevations) provided for the modeller of time-cut no. 11, i.e. Chiaveri's castle project of 1746-47, and corresponding virtual model (2008-12).

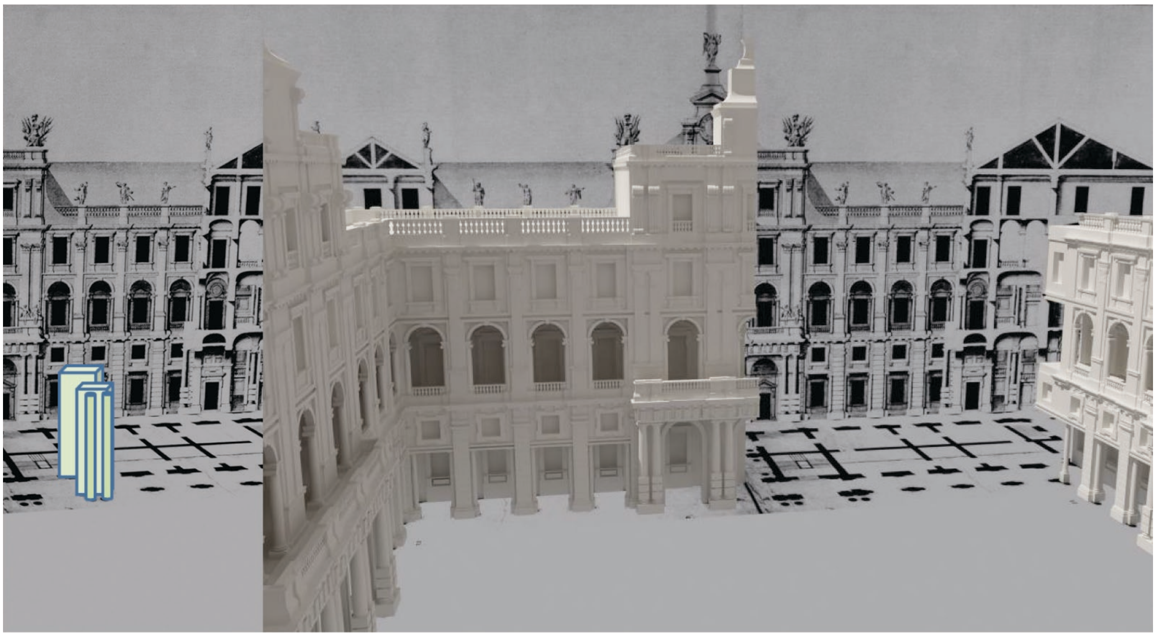

Fig. 16 Box modelling (left) and virtual model (2008-12) over the ground plan and in front of an elevation plan (right), exemplified by time-cut no. 11, i.e. Chiaveri's castle project of 1746–47 (photo collage 2012).

The box modelling technique (fig. 16) starts with very simple geometry such as a box for main buildings or cylinders for columns. They are adapted in shape to the right dimensions and placed in the correct position in the model (fig. 16 left). By this approach a rough outline of the desired object is quickly achieved and the cubature becomes visible. Afterwards a very time-consuming process of subdivision and adaptation of the representing mesh (i.e. its vertices) follows in order to elaborate the initial raw model into a more detailed architecture (fig. 16 right). Often predefined tools and modifiers (e.g. local shrinking, bending) can be used but in the end extensive work by hand is inevitable to achieve even finest details.

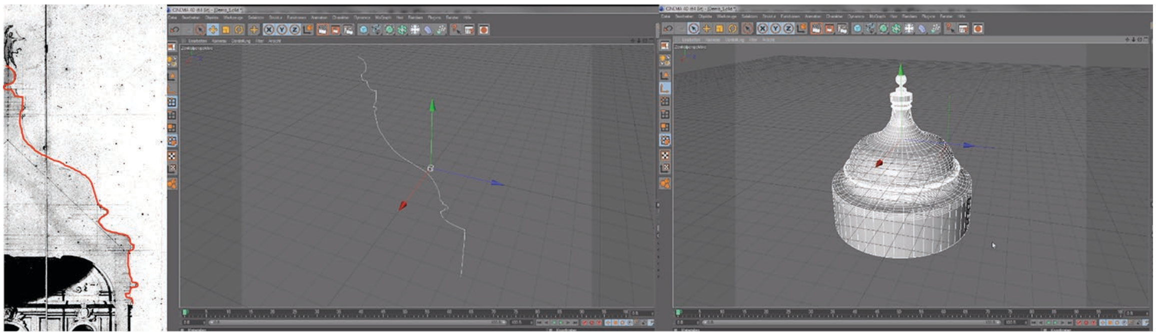

Fig. 17 Phases of the spline modelling technique exemplified by a cupola design taken out from the source material for time-cut no. 9, cf. above fig. 11, no. 9 (model fragments from 2009-10, screenshots 2012, photo collage 2012, software: Cinema 4D).

The spline modelling technique (fig. 17) consists of drawing lines (e.g. splines) for the contours of the building in some main directions on the plans. This process ends up with a line cage that can then be transformed into a mesh which is then processed as described above to model the details.

Presenting Mode of the Models

The inhomogeneous source material also required a longer readjustment process in regard to visuals because the aesthetic appearance of the reconstruction directly affects its understanding in terms of the intended knowledge transfer. On the one hand, we would like to show the current state of the Zwinger and its construction phases. On the other hand, we want to present unexecuted designs as well as building elements of a certain time period which do not exist anymore. For the representation of the existing building substance a richly-detailed, polygonal model is being used in order to create an impression of the present state as authentic as possible (fig. 18 right, 19).

Fig. 18 Inner staircase of the western central pavilion (so-called Wallpavillon) of the Dresden Zwinger
Left: photograph of the original building from 2012
Right: rendering of a textured polygon model from 2012 (software: Cinema 4D).

Regarding the representation of designs, the general aim is to interpret the historical image sources as little as possible. It was therefore attempted to transfer the source directly to the raw cubature of a building (fig. 8). However, the result distorts the visitor's spatial understanding since the components are extracted from the original context of the source image. Ultimately, the decision for the graphic realization was made for an architectonic model made out of cardboard which is the generally known type (see for example the model in fig. 15). Due to this display mode all levels of abstraction can be represented easily, the status of the modelling seems clear and the distinction or separation from the existing Zwinger buildings is obvious (figs. 8, 10; cf. also as variant fig. 19).

Fig. 19 Virtual model of the actual Dresden Zwinger (time-cut no. 14) contrasting the Baroque buildings with the added picture gallery of the 19th century by using textured and cardboard appearance (models from 2009-11, texturing 2012, rendering 2012).

If sources for a complete reconstruction are missing, the gap will either be bridged by deducing analogies from the current architectonic system (as discussed below) or by closing it neutrally, in the form of either naked cubature (fig. 20) or plastically modelled ground plans in the sense of foundation runs (fig. 21).[8] This approach guarantees that the layout of every building is represented in the model, even if there are no indications of any detail.

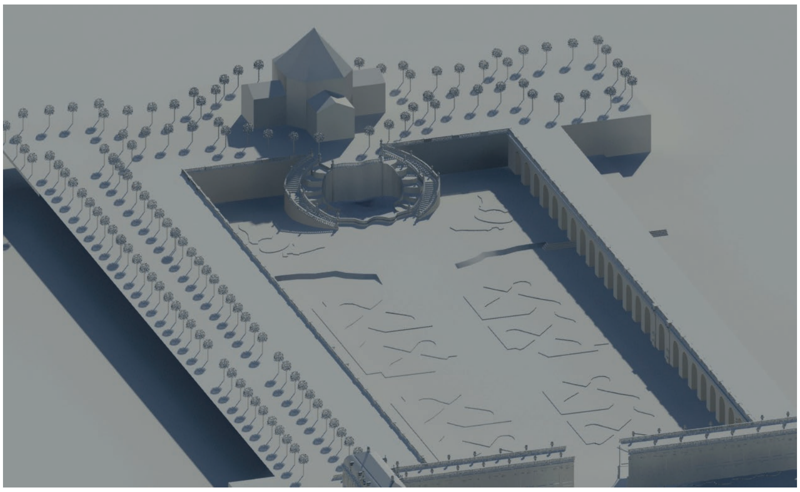

Fig. 20 Part of the virtual model (2010-11) of time-cut no. 5 with neutrally closed structure in form of naked cubatures (polygonal pavilion with projections in cross-form located on the wall terrace along the riverside; its form can be taken solely from the ground plan of the project; cf. fig. 9).

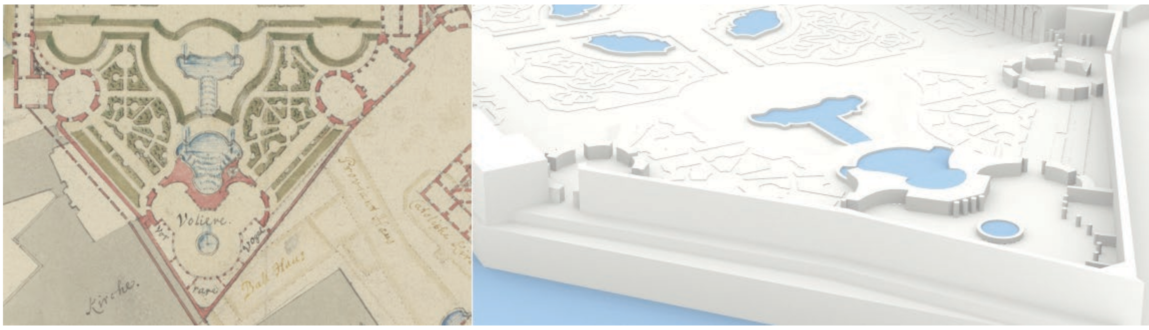

Fig. 21 Detail of the ground plan source (1716/18) for time-cut no. 6 and related virtual model (2010-11). Because of the lack of any further information the area (towered water theatre of the Zwinger garden with an aviary at the rear and adjacent rounded pavilions) is modelled neutrally in form of a plastic ground plan.

A further modelling step consists in the integration of the Zwinger buildings and projects into topographic models of the surroundings to establish correlations with the urban space. The layout of the surrounding buildings has to be conformable to the historic topographic situation of each time-cut. Their models are reduced to a neutral cubic volume to contrast with the Zwinger architecture, but accented with a few significant architectonic details for easier identification (see above figs. 7, 10).

Control of the Models

One very time-consuming and intensive task in the project was the control and revision of the models by comparison with the sources. Monthly meetings with the modellers in Dresden at the HTW made it possible to discuss the development of the models and their exactness intensively. Protocols of each session, which have been archived internally, supported the control work and will give future possibility to reconstruct the genesis of every modelled time-cut.[9] Our primary media of communication were renderings, i.e. computer generated photo shots of the models from different perspectives or views. For preparing such a meeting the actual renderings were also uploaded into the online-database (folder 'Modelle' above in fig. 13). During the control sessions double projections of the rendered model and the related source on the wall gave the possibility of comparison (fig. 22). A whiteboard was used for explaining difficult structural problems by drawing (fig. 23); sometimes we even projected the rendering of the model on this whiteboard so that we could draw on it to augment or comment the projection (fig. 24). Between the meetings some modellers also communicated via e-mail with the heads of the project to solve problems as soon as possible.

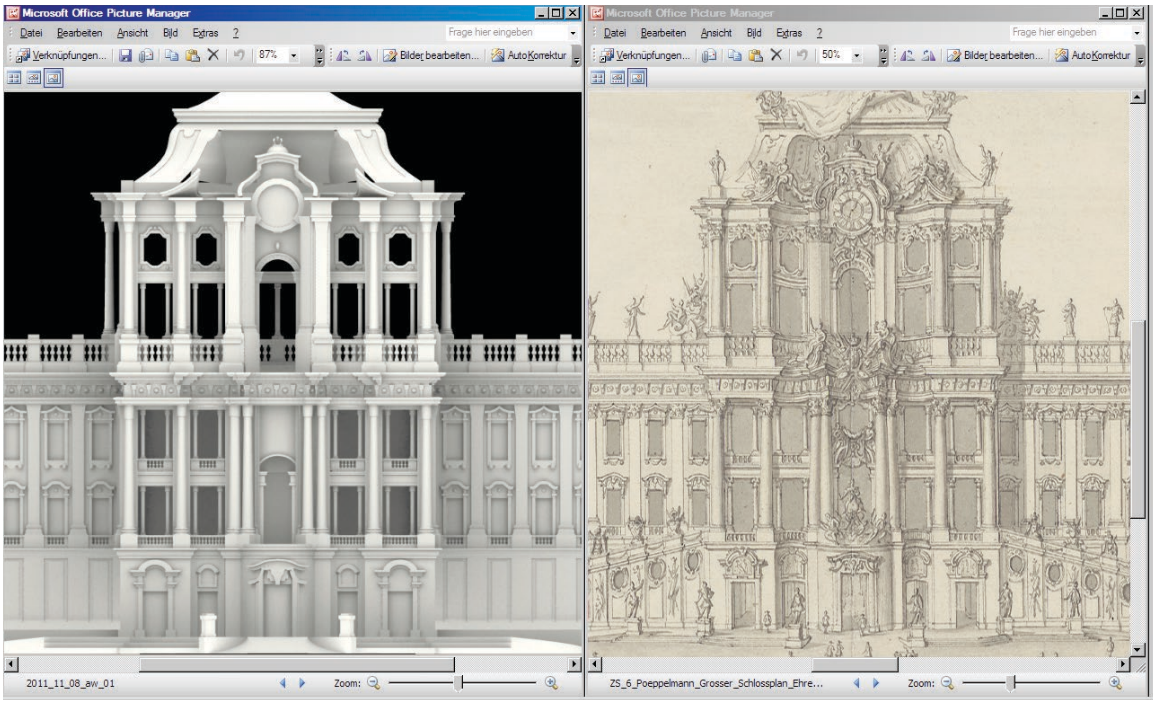

Fig. 22 Double projection of a rendered virtual model from 2010-11 (left) and the related source from 1716/18 (right), exemplified by Pöppelmann's castle project of time-cut no. 6 (in detail the complex curved and structured centre pavilion of the main cour d'honneur). Both images show the building in a mostly correlating view (software: Microsoft office picture manager, screenshot from 2012).

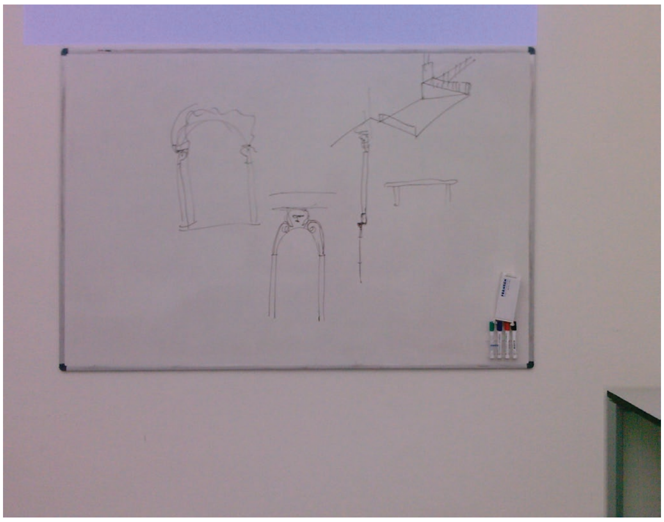

Fig. 23 Whiteboard in the conference room at HTW Dresden, used for drawn explanations of modelling problems; the violet stripe above derives from the projection light of the video beamer (photograph ca 2011, depicting details of the architecture shown in the modelling in fig. 22).

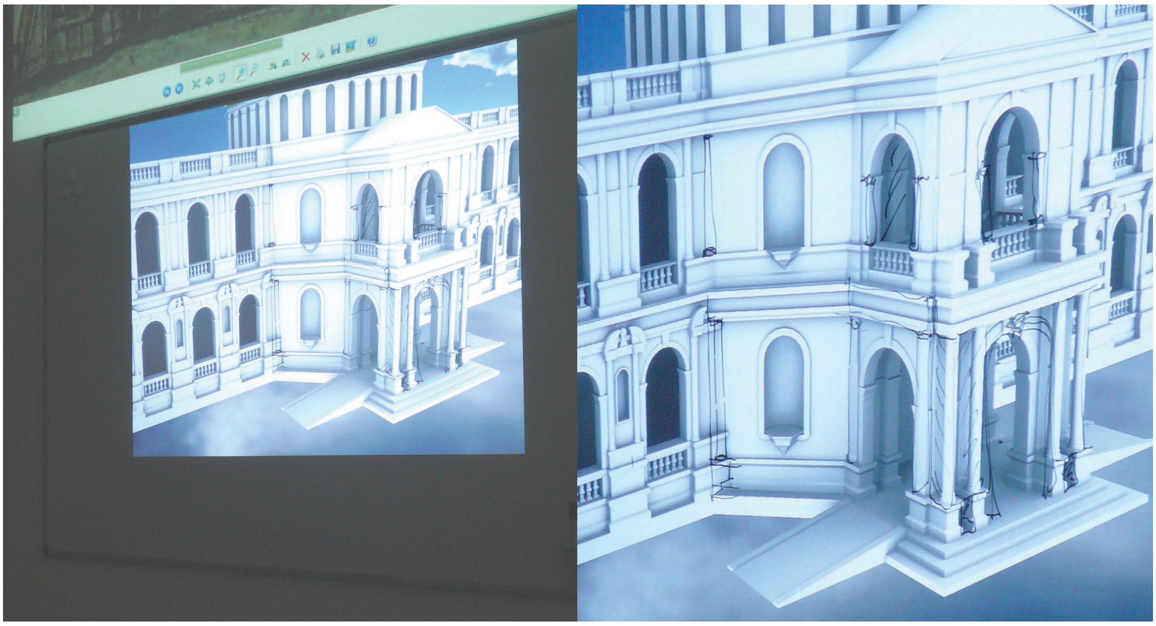

Fig. 24 Projection of a rendered virtual model from 2009-10 (detail of time-cut no. 13, i.e. garden façade of the proposed picture gallery) on the whiteboard seen in fig. 23 for the possibility of drawing corrections over the model (collage of a photograph from 2010 and a detail of it).

In some cases typological references were used to explain an insufficiently documented part of a time-cut. Time-cut no. 3 gives us a good example: The bird's eye view as the main source has been lost since World War II and is only documented by an archive photograph in black-and-white (see above fig. 4), with the effect that the three rounded pavilions which can be seen in its background are hardly recognizable. To give the modeller a better imagination of the buildings we used a comparable pavilion which is located in the Hermitage Garden of Bayreuth (fig. 25).

Fig. 25 Insufficiently documented pavilion of time-cut no. 3 (left, cf. fig. 4), being substituted by the Temple of the Sun in the Hermitage Garden of Bayreuth (middle) as pattern for the virtual model from 2011 (right).

Only in the last phase of the project the actual models were directly controlled and corrected together with the modeller in the modelling software (see above fig. 14). In order to handle the immense data masses in real time we had to use the high performance computer of the HTW's motion-capture-system.

Work and Problems with the Sources

As mentioned above, the visual sources for each time-cut consist of different media types and also of different qualities. High definition scans of original drawings and blurry scans from black and white book illustrations mark the two extremes of quality with which the modellers were confronted. We normally used book illustrations if either the originals had been lost since World War II[10] or an archive has not been able to deliver digital images of the originals. Nevertheless, book illustrations bear some general advantages compared to the reproduced originals: they are not only easier to access but also easier to handle because of comparatively small dimensions, and often free of any distortions. In the recourse to book illustrations customary scan techniques can be used in most cases without restraint and very quickly avoiding any problems of conservation connected with the originals. In fact, decisions whether book illustrations or originals should be digitized sometimes had been taken pragmatically in consideration of the respective source situation, efficiency and the modellers' special needs for detailed information. After all, the preparation of the source material was led by the general wish to make it as comfortable as possible for the modellers.

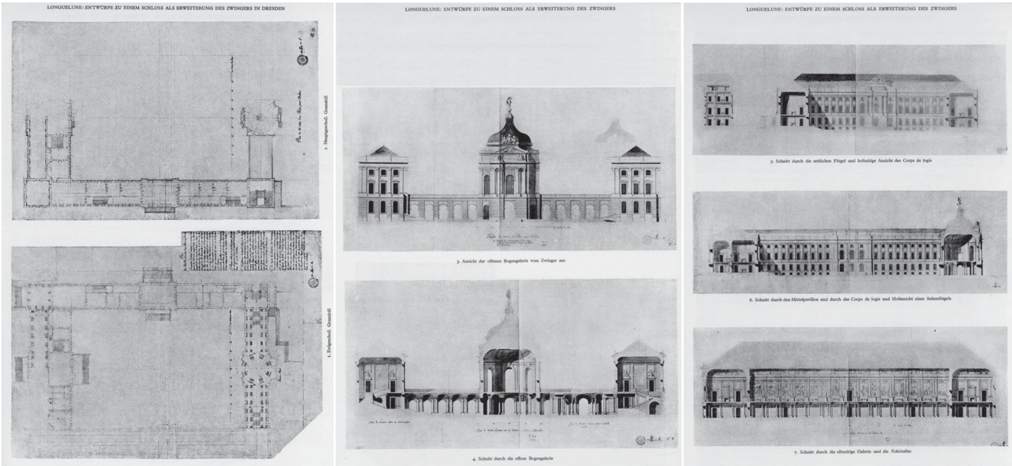

Fig. 26 Book illustrations (1953) of Baroque plan drawings (1728-1733), edited in a quarto volume, taken as source for time-cut no. 9.

An extreme example exhibits time-cut no. 9: This impressive virtual model of a castle designed by Zacharias Longuelune for the area between the Zwinger courtyard and the river Elbe (fig. 27; for the location see above fig. 5) is based on some scanned book illustrations in black and white of small size and poor quality (fig. 26). In this case, the original plan drawings are not lost but of large size with the effect that the preserving archives have had no practicable possibility to digitize it without any distortions.[11] So, unfortunately, we had to resort to the available book illustrations published in the early 1950s. The advantage of their use lay in the lack of distortions, the disadvantage in the deficiency of clarity in regard to details. But in the end the latter problem could be compensated by digital photographs of representative details taken directly of the originals.

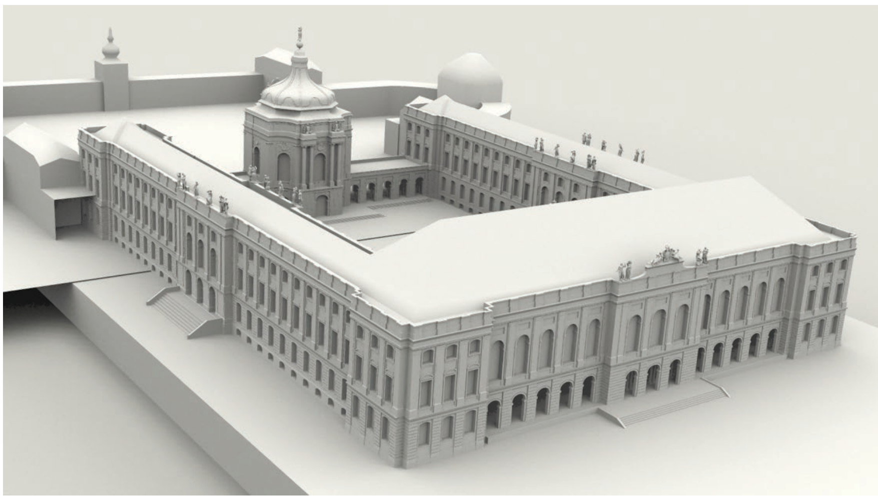

Fig. 27 Virtual model (2009-10) of Zacharias Longuelune's castle project of 1728 (time-cut no. 9).

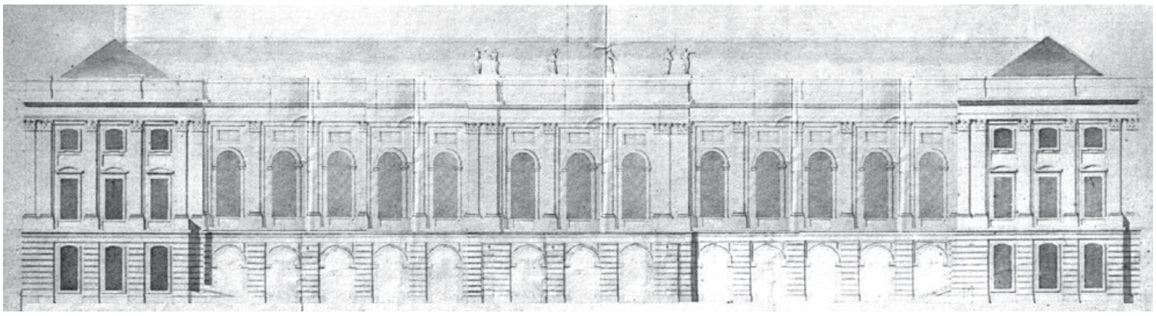

Fig. 28 Reconstruction in Photoshop of a lacking elevation for time-cut no. 9, done by using elements of the elevations depicted in fig. 24. For the virtual model generated on basis of the reconstructed elevation see fig. 24 in the foreground.

The most striking problems during the definition of time-cuts regarding unexecuted projects were either the partial lack of visual sources or the discrepancy of measured ground plans and elevations – or both. For this reason reconstructions have seemed to be indispensable in order to avoid any larger gaps which could irritate or even disillusion the recipient of the virtual model. To fill those gaps in a believable way it is necessary to base the reconstruction on different critical principles. One of them is the deduction from the documented parts of the building project itself. In the case of the aforementioned time-cut no. 9, for example, one front elevation is lacking, namely that of the gallery wing located at the rear of the castle along the riverside. The reconstruction therefore could be completed on the one hand from the existing ground plan together with the sections of this building wing and on the other hand from the homogenous architectonic system which allowed the borrowing of elements from the documented façades. The strict orthogonal projection of the existing plans gave the possibility to produce easily an elevation as instruction tool for the modeller, because the usable façade elements could be brought in a new order with the help of Photoshop software (fig. 28). While this comfortable method of reconstruction was the preferred one, in the worst case, if orthogonal projected plans had been completely lacking, elevations or ground plans would have had to be reconstructed in the form of schematic drawings (with the added problem that none of the leading team members is a professional draughtsman). For this issue the following problem of reconstruction will give an example:

A missing ground plan is of no further problem if one has to deal with cubic architecture. However, it turned out to be a big one for the modellers if the buildings show curvatures and complex systems of columns, pilasters, or lesenes since in orthogonal projected elevations these aspects are not sufficiently readable. As an example for this problem we can take one of the tower buildings of time-cut no. 5: The situation plan shows schematic and inaccurate ground plans for two gateway towers and one fountain tower (see above fig. 9). Two final planning states of these buildings had been published in elevations by Pöppelmann in his own copperplate edition about the Zwinger.[12] Unfortunately, their basement level differs in its form so much from the situation plan that the reconstruction could not be limited to the buildings itself but also had to include the course of the connecting colonnades. A schematically drawn ground plan was necessary to precisely instruct the modeller (fig. 29).

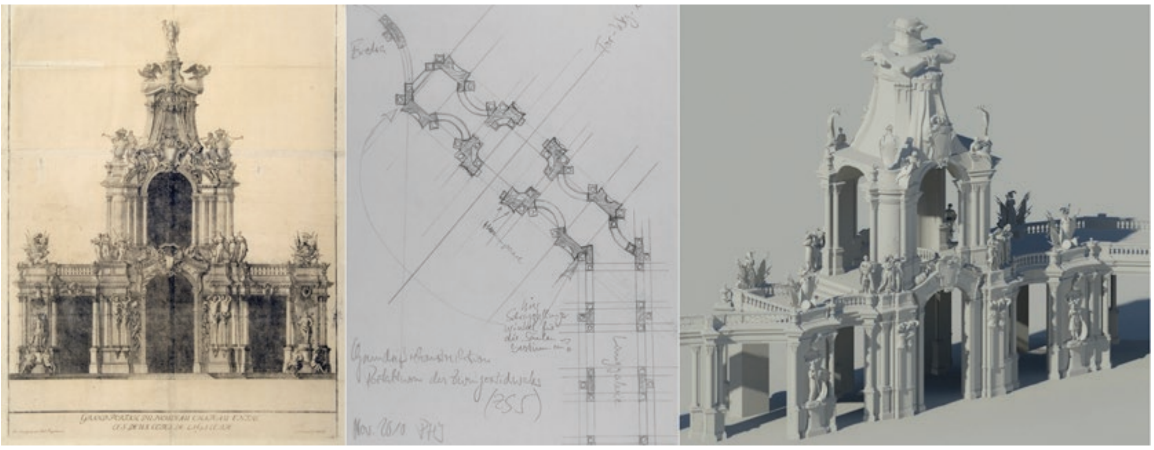

Fig. 29 From elevation (copperplate from 1729) via a sketched reconstruction of the ground plan (2010) to the virtual model (2010-11), exemplified by a gateway tower of time-cut no. 5 (cf. above fig. 9).

The lack of a ground plan can also lead to great difficulties if as elevation only a perspective view of a project has survived like in time-cut no. 3 (see above fig. 4). In this case an existing ground plan correlates only partially with the bird's eye view taken as the main source for the virtual model (fig. 30). A further complication is caused by the fact that the area of inadequateness in the ground plan is solely depicted at half in the elevation source: One can recognize there a tilt-yard flanked by one half of an edifice to be used for festivities. The gap, consisting first of all in a second yard near the riverside, was closed by repeating some recognizable elements from the tilt-yard like the monumental gateway, outside staircase and retaining wall, while the building was completed by mirroring the depicted half. Common building logic gave evidence for the addition of a huge symmetrical staircase hall at the rear of the edifice; the latter naturally conform to the architectonic system of the front façade. Finally the proportions of all the unexecuted buildings had to be found for lack of measured elevations in adjustment with the existing Zwinger architecture.

Comparable to the so far exemplified deductive methods of critical reconstruction is the borrowing of forms from typologically related buildings or designs of the same architect. This was done, for example, in time-cut no. 13 which represents Gottfried Semper's grand forum project. The elevation of the proposed museum building is documented only by a perspective visualization of the project which shows the building on the left with its main façade of the garden side in an extremely shortened view in which all details are unrecognizably distorted (fig. 31). And while nothing of the other main façade on the town side can be seen, only one narrow side of the building is depicted frontally. So in this case, both main façades including the monumental staircase projection on the town side had to be reconstructed. As measured source material only a ground plan published by Semper exists which could give some orientation.[13] Patterns usable for the reconstruction had been fortunately found in the context of Semper's alternative designs for the Zwinger area. So, the staircase projection of the town façade could be deduced mostly without any alterations from a preparatory sketch for the museum project which proposes for the first time the finally chosen building site (fig. 32). More difficult to reconstruct was the ground storey of the façades because in the source in that area one can only recognize the shadows of some cornices, the arcades and above them some obscure dark spots which have been interpreted as medallions. All these motifs are assembled again at the outer main façade of Semper's executed museum building but there in a varied combination. As often done, the modeller undertook their recombination by some trial-and-error attempts and supported by a sketched elevation drawing (fig. 33).

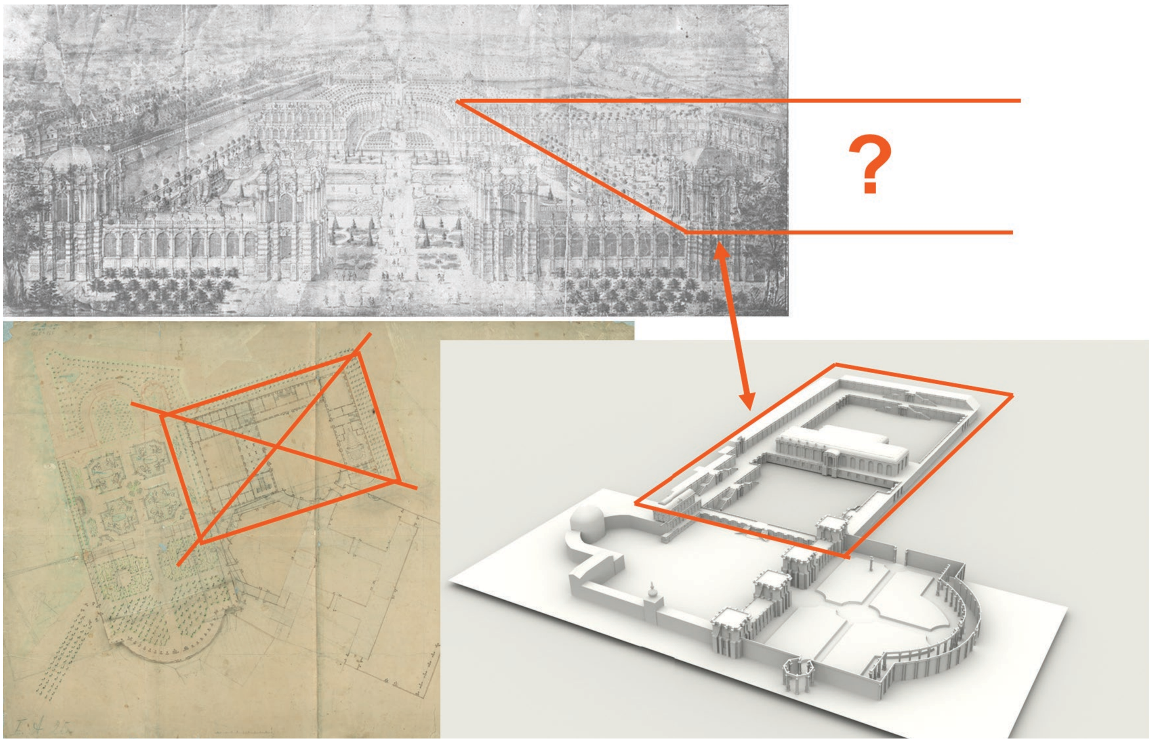

Fig. 30 Confrontation of sources (bird's eye view of fig. 4 and relatable ground plan from 1712/13) and virtual model (2010-11) for time-cut no. 3. The red frames mark a zone of insufficient and inconsistent documentation which had to be modelled partially as a free interpretation but consistently to the architectural system depicted in the elevation source.

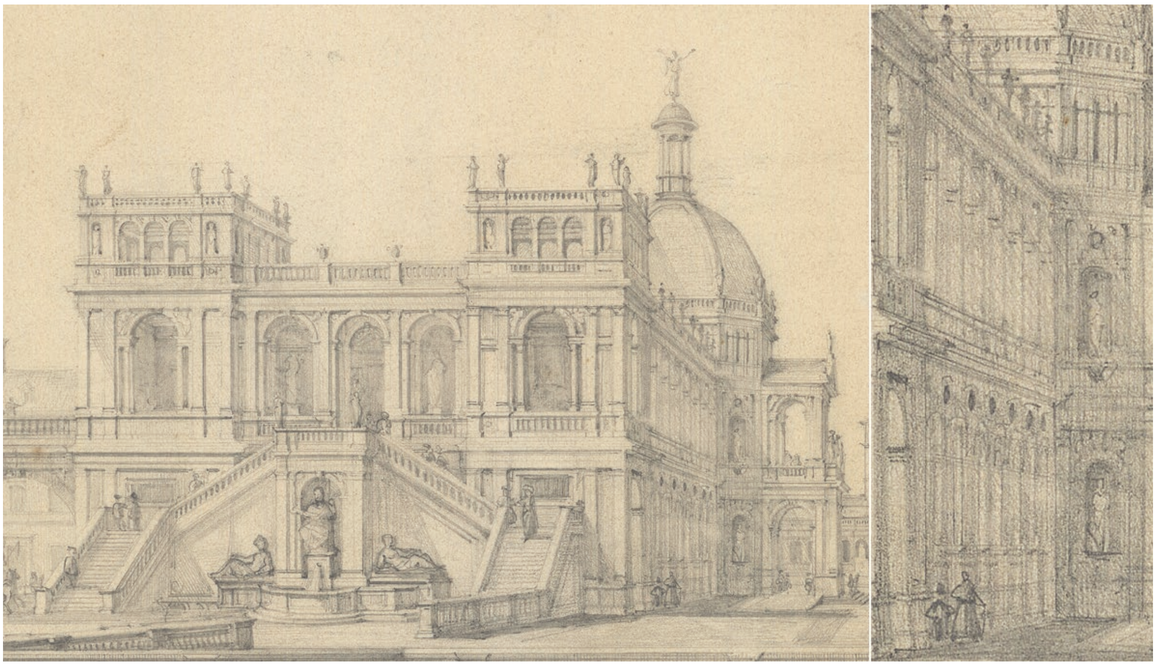

Fig. 31 Details of the main elevation source from 1842 for time-cut no. 13 (cf. above fig. 11, no. 13), showing in extreme perspective distortion Gottfried Semper's proposal for a picture gallery which is laid out in front of the residential castle.

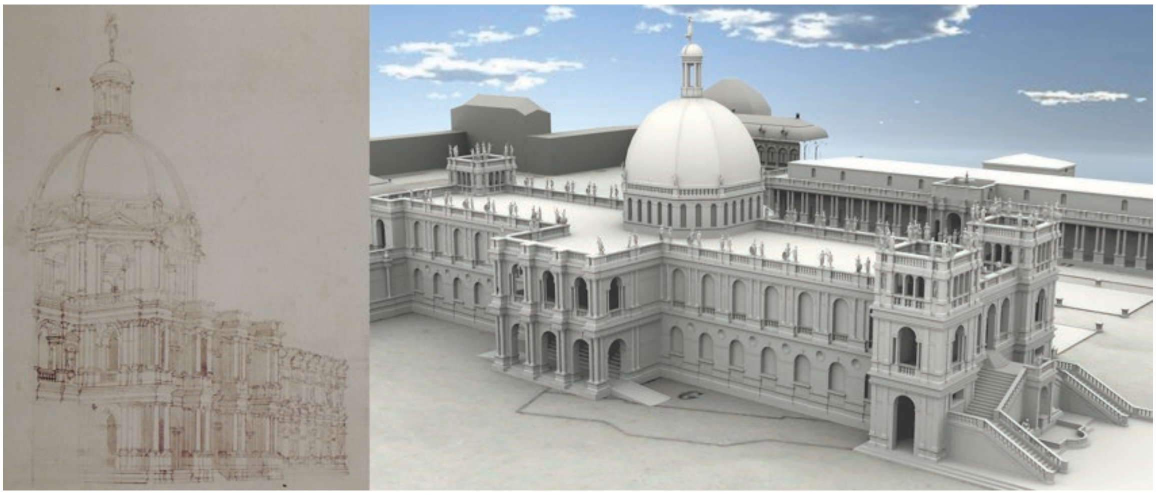

Fig. 32 Sketched design from 1840 of Gottfried Semper for a picture gallery used as pattern for the virtual reconstruction of an insufficiently documented alternative design (time-cut no. 13; cf. fig. 31), namely for the staircase projection at the town side (virtual model 2009-11).

Fig. 33 Reconstruction of the ground storey of Gottfried Semper's design for a picture gallery in front of the residential castle (time-cut no. 13; cf. fig. 31) by borrowing motifs (medallions, cornices, pillar arcades) from the outer façade of the executed building (virtual model 2009-11).

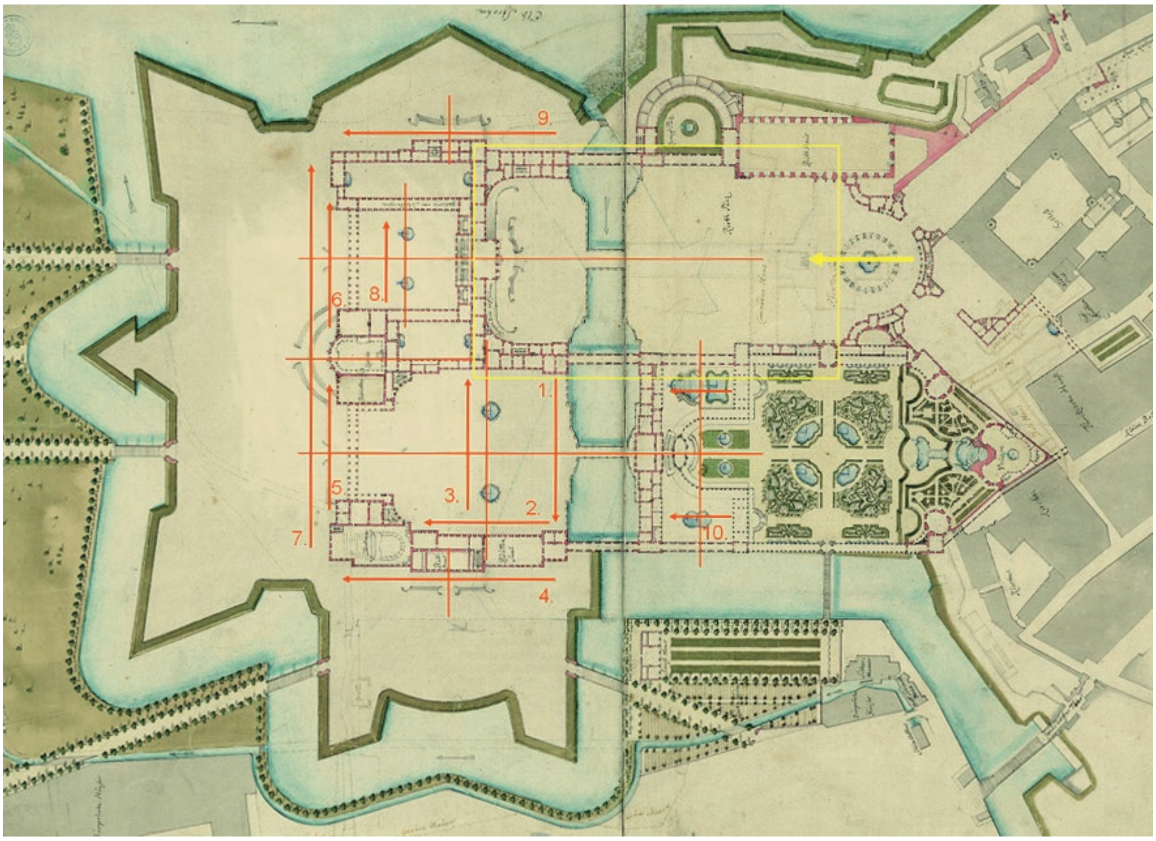

Fig. 34 Situation plan of Pöppelmann's Grand Castle Project from 1716-18 (time-cut no. 6). The yellow frame marks the area depicted in fig. 35. Red arrows together with red lines as symmetry axes mark the ten mirroring steps which had been necessary to reconstruct virtually the complete building cubature of the castle (graphical overlay 2012).

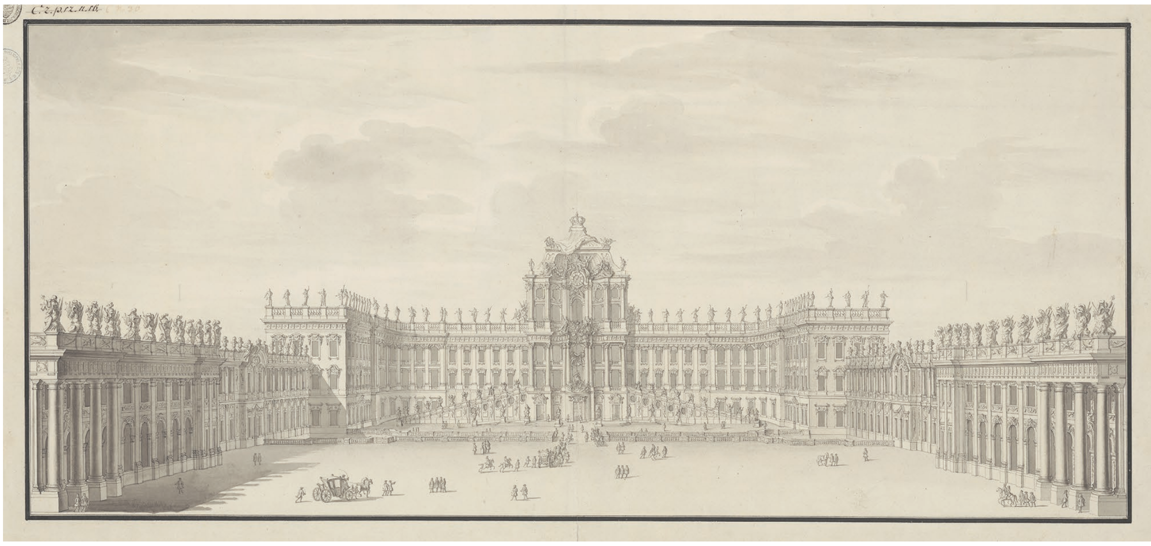

Fig. 35 Perspective view in the main cour d'honneur of Pöppelmann's Grand Castle Project from 1716-18, being the one and only elevation source for time-cut no. 6.

A further used deductive principle of critical reconstruction, the deduction of forms and structures from typologically and stylistically related buildings, was already mentioned above in the case of the octagonal pavilions of time-cut no. 3 which are documented only by an unclear perspective view of a small size (see above fig. 25).

Another guideline of critical reconstruction was based on the baroque architectural principle of symmetry. This principle proved to be very successful in the reconstruction of time-cut no. 6 representing Pöppelmann's so-called Grand Castle Project which reduces the Zwinger courtyard to a secret garden of a gigantic residential area with three cours d'honneur. From this ambitious design we only have the situation plan (fig. 34) and an impressive perspective view of the main cour d'honneur (fig. 35). The remaining two cours d'honneur on the rear can be completed in most parts by mirroring one side wing of the depicted corps de logis, first to the left side and from there inside the court, then along the rear front to the right side, afterwards inside the right court and finally along both outer side façades as shown in the diagram of fig. 34. In addition, the position of colossal columns could be read out of the situation plan by comparison of diameters because in the perspective view some of those colossal columns are depicted and therefore locatable. The result of this reconstruction attempt is an impressive virtual model which allows experiencing plastically the vast dimensions of an excessive Baroque building project (fig. 36).

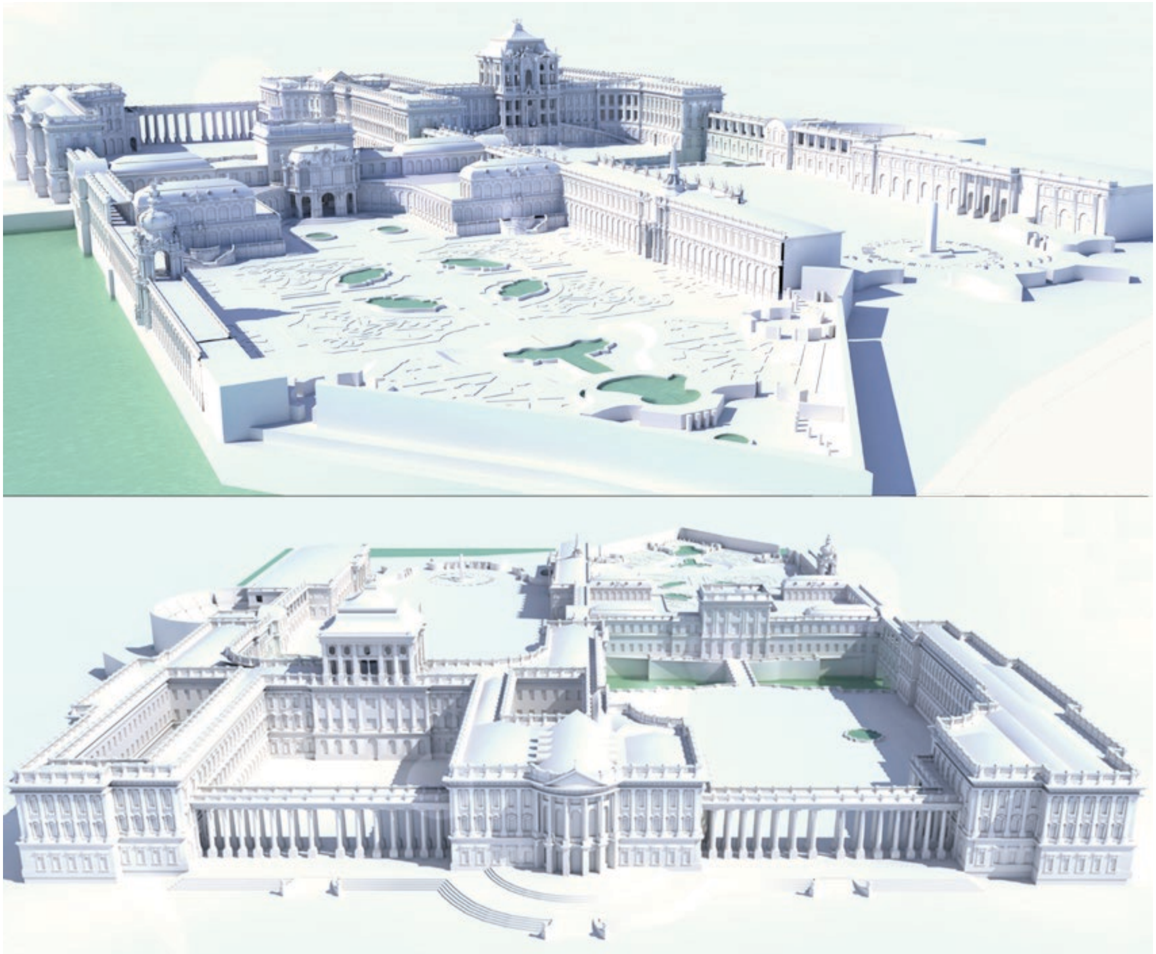

Fig. 36 Virtual model (2010-11) of Pöppelmann's Grand Castle Project from 1716-18 (time-cut no. 6).

Scientific Results

The virtual reconstruction of the Dresden Zwinger developed during the described project gives us a deeper analytic insight into the historic planning process and its inherent problems. For example, from rectifying the perspective view of time-cut number 6 we were able to learn how much the historic media of architectural visualization can deceive us: If you count the axes strictly according to the ground plan, the virtual model demonstrates that some parts of the side façades show a somewhat strange disproportion while they do not appear to do so in the distorted perspective view (fig. 37).

Taking into consideration the many discrepancies between ground plans and elevations we have to ask if this is the result of a fragmentary conservation or of a drafting process which continues during the drawing process. In our opinion it is plausible that, while an elevation plan was being drawn, alterations to an already existing ground plan could be made by the architect and directly integrated into the new elevation drawing. In fact, before the acceptance of a project it was not really necessary that all the plans made for it correspond to each other since discrepancies could be taken in a positive sense as alternative proposals. A need for coordination was only given if the plans would have had to fulfil a function on an actual construction site. The refusing of a draft must have made such coordination work seem like an additional and, in the end, senseless toil, with the effect that partially non-correlating plans could be archived.

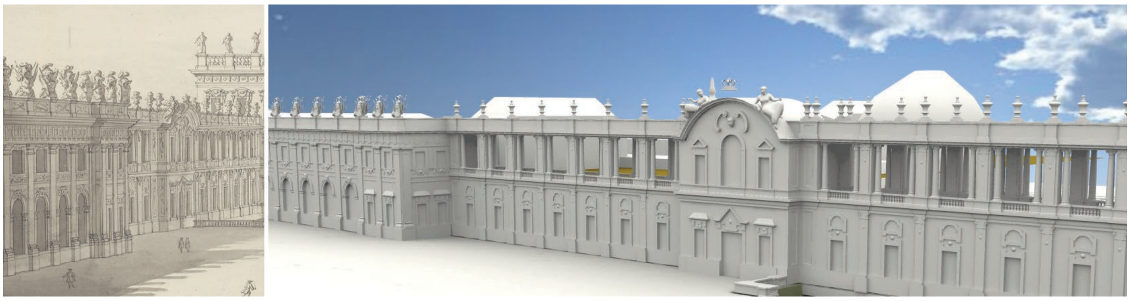

Fig. 37 Perspective distorted detail in the elevation source for time-cut no. 6 (cf. fig. 35) and its rectifying by the virtual model (2010-11). The axes of the architecture appear slender in the historic depiction but broad and portly in the model.

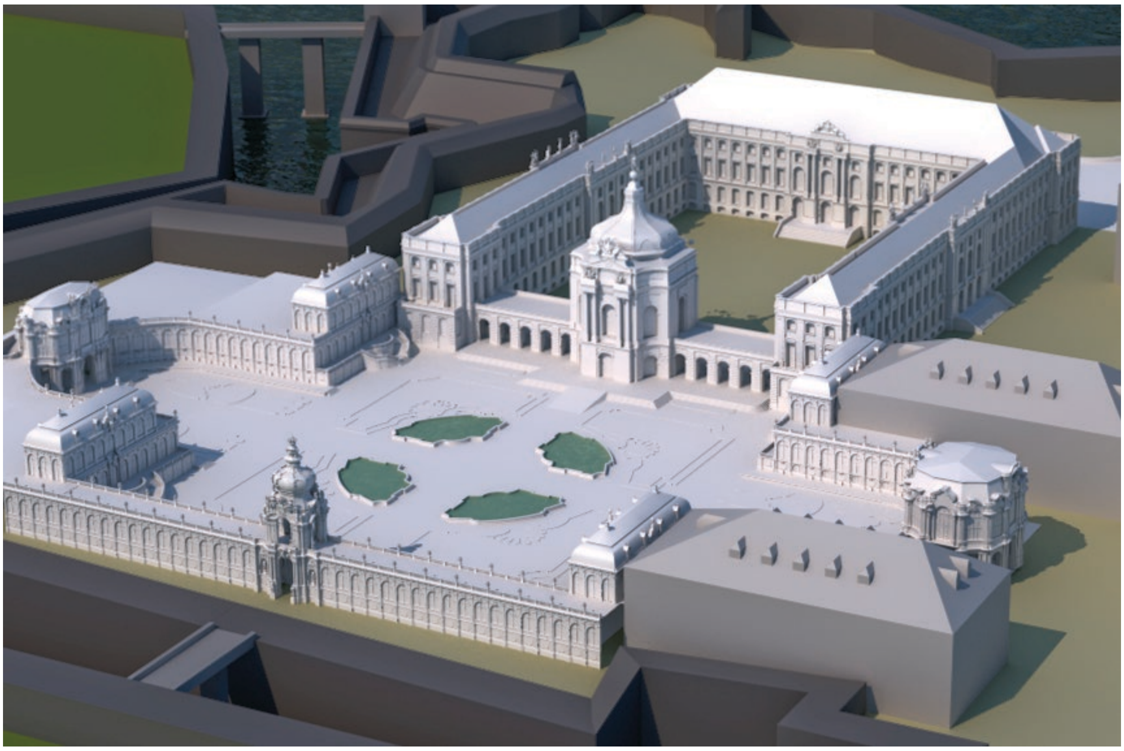

Fig. 38 Virtual model of Zacharias Longuelune's castle project 1728 (time-cut no. 9) in addition to the already existing Zwinger courtyard (modelling of the court of the Zwinger 2009-11, extension of the castle 2009-10, surroundings 2011-12, merging of the individual models 2013, rendering 2013).

Highly illuminating was the possibility to combine the castle projects of Pöppelmann's successors with the Zwinger courtyard erected by him. In the 18th century, such a combination was obviously mostly done in two-dimensional situation plans but only seldom in elevations. One fine example is the central polygonal pavilion of Zacharias Longuelune's castle project (time-cut no. 9) which was supposed to become the counterpart of Pöppelmann's crowned gateway tower (so-called Kronentor; see above fig. 2). As an isolated form in the elevation plan the pavilion looks precious and delicate (see above fig. 26, middle column). In combination with Pöppelmann's architecture, however, it takes on a monstrous aspect. The Zwinger courtyard almost appears like the front garden of a somewhat oversized castle (fig. 38, cf. also fig. 27).

Conclusion

The project 'Back to the future – Visualizing the Planning and Building of the Dresden Zwinger', initiated by the Saxon Administration of State-owned Castles and Gardens, had begun with a certain museum-didactic aim: the building development and planning history of the Dresden Zwinger should be modelled virtually for instructing future visitors of that famous Baroque building. But in the course of the project's progress it has in the end also achieved some scientific results of diverse value. As primary output fourteen more or less complex virtual three-dimensional models of construction and planning phases (so-called time-cuts) have been produced including a richly-detailed one of the existing buildings as well as fourteen schematic ones of the historic correlating surroundings. This result must be taken as the admirable work of more than two dozens of students who participated in the degree program of Media Computer Science taught at the Dresden University of Applied Sciences (HTW). The scientific output on the one hand consists of the remarkable number of image and plan sources which were, as preparation, collected and in parts newly arranged, and on the other hand in the elucidating new information which the virtual models can give about the truthfulness of an historic image source and, as in the case of a not realized draft, about its structure, logic, correlation, quality and possibility of realization. Correlation in context with the latter means the interaction between such a draft and the adjacent historic, as well as actual urban space. To sum it up: verification with the help of virtual reconstruction and building simulation.

Meanwhile, the fourteen virtual models are waiting in a raw state for the production of an adequate presentation form because, as already mentioned, in the end the visitors of the famous Dresden Zwinger shall be their primary recipients. A first attempt has already been made when a video including the time cuts 1 to 8, 12 and 13 was produced for the exhibition 'Pöppelmann 3D – Bücher, Pläne, Raumwelten' presented in Dresden in the Saxon State and University Library (Sächsische Landesbibliothek – Staats- und Universitätsbibliothek – SLUB) from 16 May until 1 September 2013.[14] The reactions of the audience were mostly that of surprise due to the fact that the film was able to show so many unknown aspects about such a supposedly familiar building as the Zwinger. It goes without saying that the building simulation of Pöppelmann's stupendous unexecuted drafts created a great amount of amazement. As expected, our project reveals that looking back in history via virtual models to obtain results for future knowledge really works!

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Preliminary remark: Only a selected bibliography concerning the architectural history of the Dresden Zwinger is given. Complementary to the topic of this article see Jahn and Welich 2009.

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Illustrations

Preliminary remark: For all virtual models depicted in the illustrations (fig. 8, 10, 14-22, 24, 25, 27, 29, 30, 32, 33, 36-38), and any reproductions of them, the copyright is held by Staatliche Schlösser, Burgen und Gärten Sachsen gGmbH, Dresden. Hereafter for these illustrations only the names of the modellers are given as additional information.

Fig. 1-2, and 5 Dresden, Staatliche Schlösser, Burgen und Gärten Sachsen gGmbH.

Fig. 3 Dresden, Sächsisches Staatsarchiv, Hauptstaatsarchiv, Rißfach 99, Nr. 14. (Black and white photograph of the 1709 drawing)

Fig. 4 Dresden, Sächsische Landesbibliothek – Staats- und Universitätsbibliothek – SLUB, Deutsche Fotothek, Hauptkatalog 0095526.

Fig. 6 Dresden, Staatsbetrieb Sächsisches Immobilien- und Baumanagement – SIB, IS-Objekt-Nr. G 001442, Plannr. 05.

Fig. 7 Modellers: Philipp Hackbarth, Falk Schieber and Steve Kuttig (Zwinger buildings), Romy Ebert (surroundings), Rainer Uhlemann (adjusting of both models).

Fig. 8 Modeller: Markus Zönnchen.

Fig. 9 Photomontage by Peter H. Jahn of a ground plan (Dresden, Sächsisches Staatsarchiv, Hauptstaatsarchiv, OHMA P, Cap. I A, Nr. 26, Bl. 1-3), an elevation drawing (Dresden, Sächsische Landesbibliothek – Staats- und Universitätsbibliothek – SLUB, Kartensammlung B 1978), and three printed elevations (Matthäus Daniel Pöppelmann, *Vorstellung und Beschreibung* […] *Der Königl.*[ichen] *Orangerie zu Dreßden* [Dresden, 1729]).

Fig. 10 Modellers: Philipp Hackbarth, Falk Schieber and Steve Kuttig (Zwinger buildings in beige colour), Chris Leister and Toni Seifert (Zwinger buildings in white colour), Romy Ebert (surroundings), Rainer Uhlemann (adjusting of the models).

Fig. 11 Photomontage by Peter H. Jahn of different image sources mostly preserved in the archives mentioned in endnote 4. Exceptions are no. 8, which shows a painting in possession of Staatliche Kunstsammlungen Dresden, Gemäldegalerie Alte Meister, and no. 13; for the latter see below fig. 31. Detailed information about no. 6 is given below at fig. 35 and about no. 9 at fig. 26.

Fig. 12 Written by Peter H. Jahn.

Fig. 13 See impressum of the webpage: http://www2.htw-dresden.de/~zwinger/webs/impress.html.

Fig. 14 Screenshot of a virtual model uploaded in the modelling software (Modeller: Anne Weinert).

Fig. 15 Photomontage by Peter H. Jahn of a diagram (author: Loreen Pogrzeba) and a virtual model (modeller: Josephin Seibt).

Fig. 16 Photomontage by Markus Wacker (modeller: Josephin Seibt).

Fig. 17 Photomontage by Markus Wacker basing on three screenshots of a virtual model (modeller: Rainer Uhlemann).

Fig. 18 Photomontage by Markus Wacker of a photograph (photographer unknown) and a rendering of a virtual model (modeller: Steve Kuttig).

Fig. 19 Modellers: Philipp Hackbarth, Falk Schieber and Steve Kuttig (Baroque Zwinger buildings; texturing also by Kuttig), Michael Marschner (picture gallery).

Fig. 20 Modeller: Chris Leister.

Fig. 21 Photomontage by Peter H. Jahn of details of fig. 34 and the model depicted in fig. 36 (modeller: Conny Coburger).

Fig. 22 Modeller: Anne Weinert; for the depicted source at the right half see fig. 35.

Fig. 23 Dresden, Hochschule für Wirtschaft und Technik.

Fig. 24 Dresden, Hochschule für Wirtschaft und Technik (modeller: Michael Marschner).

Fig. 25 Photomontage by Peter H. Jahn of a detail of fig. 4, an own photograph and a screenshot of a virtual model (modeller: Rainer Uhlemann).

Fig. 26 Franz 1953, plates I-III, fig. 1-7.

Fig. 27 Modeller: Rainer Uhlemann.

Fig. 28 Photomontage by Peter H. Jahn, using details of Franz 1953, plates II and III, fig. 3, 5 and 6.

Fig. 29 Photomontage by Peter H. Jahn, using a printed elevation (M. D. Pöppelmann, *Vorstellung und Beschreibung […] Der Königl.[ichen] Orangerie zu Dreßden* [Dresden, 1729]), an own drawn pencil sketch and a rendering of a virtual model (modeller: Chris Leister).

Fig. 30 Photomontage by Peter H. Jahn of fig. 4, a ground plan (Dresden, Sächsisches Staatsarchiv, Hauptstaatsarchiv, OHMA P, Cap. I A, Nr. 25a, Bl. 1-3) and a rendering of a virtual model (modeller: Rainer Uhlemann).

Fig. 31 Zurich, Eidgenössische Technische Hochschule (ETH), Institut für Geschichte und Theorie der Architektur (gta), estate of Gottfried Semper, n. 20-052-1/MV 52-1-1.

Fig. 32 Photomontage by Peter H. Jahn of a sketched architectonic draft (Dresden, Sächsisches Landesamt für Denkmalpflege, Plansammlung, M 52. C. Bl. 15 / MV 89 g- 41-5) and a rendering of a virtual model (modeller: Michael Marschner).

Fig. 33 Photomontage by Peter H. Jahn of a photography (photographer: Uwe Miersch, Oßling; source: http://www.dresden-und-sachsen.de/dresden/sempergalerie.htm, last accessed on 09.07.2015) and a rendering of a virtual model (modeller: Michael Marschner).

Fig. 34 Photomontage by Peter H. Jahn basing on a ground plan (Dresden, Sächsisches Staatsarchiv, Hauptstaatsarchiv, Ing. Corps Dresden Nr. 35e).

Fig. 35 Dresden, Sächsisches Staatsarchiv, Hauptstaatsarchiv, Ing. Corps Dresden Nr. 35c.

Fig. 36 Modellers: Philipp Hackbarth, Falk Schieber and Steve Kuttig (Zwinger courtyard); Conny Coburger and Anne Weinert (castle).

Fig. 37 Photomontage by Peter H. Jahn of a detail of fig. 35 and a rendering of a virtual model (modeller: Conny Coburger).

Fig. 38 Modellers: Philipp Hackbarth, Falk Schieber and Steve Kuttig (Zwinger courtyard), Romy Ebert (surroundings), Rainer Uhlemann (castle; adjusting of all models).

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[1] As authorship is divided conform to the leading responsibilities within the project, the parts of the text concerning its conception are written by Dirk Welich, those related to technical aspects of computer modelling by Markus Wacker, and those related to preparatory and accompanying architectural historic research and its results by Peter Heinrich Jahn. The latter has done the editorial work, following Markus Wacker's proposal for organizing the arguments. Thanks for partial preliminary copy-editing to Anne Kleiner as well as to Jessica Buskirk and Bertram Kaschek. The heads of the project are Mr. Welich as representative of the commissioning institution and Mr. Wacker as that of the cooperating one.

[2] The name of the building derives from this special location: 'Zwinger' means the outer courtyard between a castle and its outer wall.

[3] A first attempt of such a teaching video will be mentioned at the end of this text.

[4] The four most important of these archives are: Sächsisches Staatsarchiv, Hauptstaatsarchiv (Saxon Main State Archives), Sächsisches Landesamt für Denkmalpflege, Plansammlung (Plan Collection of the Saxon State Bureau of Monument Protection), Sächsische Landesbibliothek – Staats- und Universitätsbibliothek – SLUB (Saxon State and University Library), and Staatliche Kunstsammlungen, Kupferstichkabinett (Graphical Cabinet of the State-owned Art-collections). Detailed references to used sources and secondary literature for time-cuts 1-8 are already given by Jahn and Welich 2009. A follow-up article concerning time-cuts 9-14 is still a desideratum.

[5] Matthäus Daniel Pöppelmann, *Vorstellung und Beschreibung Des von S[eine]r. Königl.[ichen] Majestät in Pohlen, Churf[ürst]l.[ichen] Durchl.[aucht] zu Sachßen/ erbauten so genannten Zwinger=Gartens Gebäuden, Oder Der Königl.[ichen] Orangerie zu Dreßden* (Dresden: self-published by the author, 1729). For a commented facsimile-reprint reduced to small size, see Keller 1980.

[6] For a list of all modellers see the webpage of the project:
http://www2.htw-dresden.de/~zwinger/webs/mitwirk.html.

[7] With the exception of some diaphanous gateway buildings like that of time-cut no. 5 (cf. figs. 10, 29).

[8] If the insufficiently documented structure was too complex, the modelling of a ground plan was preferred.

[9] The protocols were written until May 2009 by Loreen Pogrzeba, and from then on by Conny Coburger and Anne Weiner.

[10] This is still a serious problem in Dresden. Sources were either burnt by fire during air raids or they are missing as a result of evacuation paired with misplacement or even displacement.

[11] Namely the Plan Collection of the Saxon State Bureau of Monument Protection (for the official German name see above note 4). The same procedure was necessary for modelling time-cut no. 11. In this case the plan sources were taken from Sponsel 1924, plates 87-91 (cf. fig. 15).

[12] Cited above in note 5.

[13] Gottfried Semper, *Das königliche Hoftheater zu Dresden* (Braunschweig: Vieweg, 1849), plate I.

[14] Implemented as a cooperation between ENBaCH – European Network for Baroque Cultural Heritage, represented by the Institute of Romance Philology of the Technical University Dresden, Faculty of Philology and Cultural Humanities (Institut für Romanistik der Technischen Universität Dresden, Fakultät Sprach-, Literatur- und Kulturwissenschaften), SLUB (as fully named above in the text) and the Saxon Administration of State-owned Castles and Gardens (Staatliche Schlösser, Burgen und Gärten Sachsen gGmbH). The mentioned teaching video was produced by Rainer Uhlemann. A work of the same is also a demo-trailer of 2012 which was shown at public presentations of the 'Zwingerteam' project, one time within the 'Mitschnitt-Festival' of the HTW Dresden in 19 July 2012 and another time during a press conference dedicated to the project in 12 March 2013; both events were held at the 'ufa-Palast' cinema in Dresden. While at this time a future public presentation of the exhibition film is quite unclear, the demo-trailer can be seen online: http://vimeo.com/46621228.

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PALATIUM *e*-Publication 3

This volume deals with digital reconstructions and visualizations of palaces, castles, and other kinds of residential architecture of the early modern period. It focuses not so much on the digital modelling of extant buildings, but rather on the virtual reconstruction of 'lost' buildings – in particular of palaces destroyed or drastically altered, or which were never actually built in the first place.

These diverse case studies presented here explore a range of approaches and methods of using virtual reconstructions as tools for both scientific research and dissemination to a wider public. They address problems such as the visualization of uncertainties, the dynamic modelling of a building's evolution through time, and the use of digital reconstructions as repositories of data and knowledge.

The numerous digital models and associated images discussed in this volume display an enormous variety in terms of the underlying technology, data conceptualization and visual style. Such adaptability means that this new medium finds considerable application in architectural history and related disciplines. It also means that digital reconstructions ought to be regarded as cultural products and therefore become objects of scholarly research in their own right.

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