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

Heike Messemer (Ludwig-Maximilians-Universität München, Germany)

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]

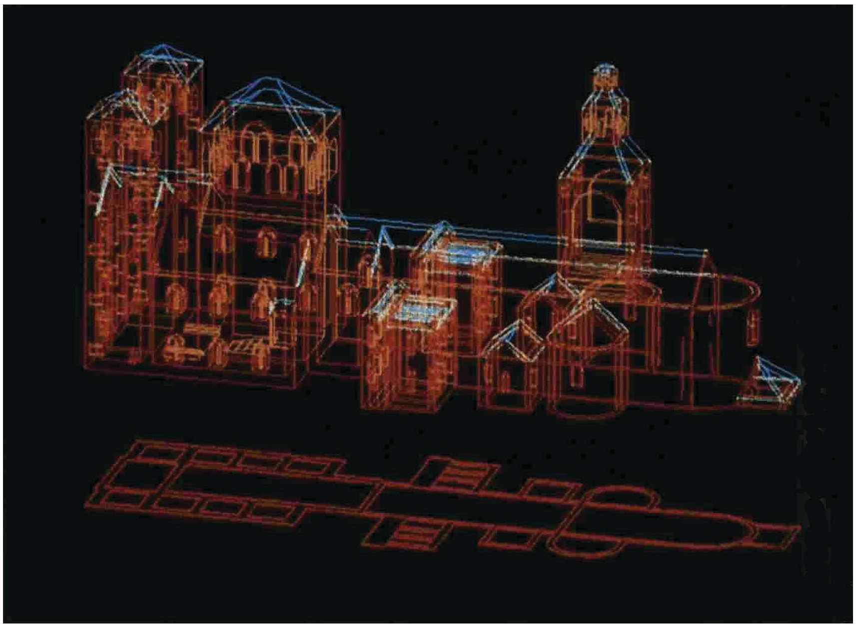


Fig. 2 Wireframe model of Old Minster created at the IBM UK Scientific Centre, Winchester, in 1984-1986.

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.

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]

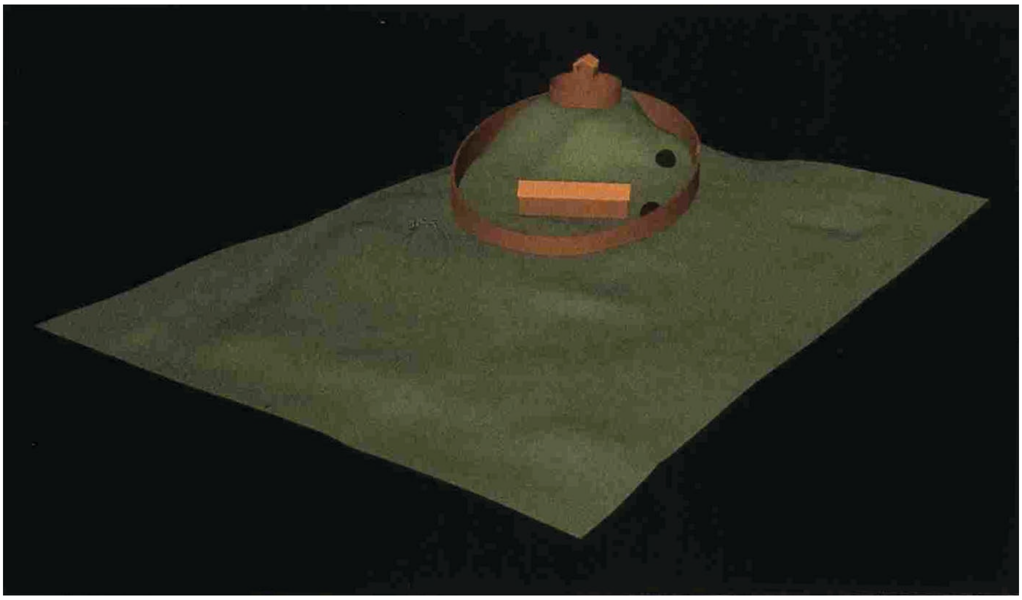


Fig. 4 Solid terrain model with reconstruction of motte-and-bailey, Mathrafal in Wales, UK, generated in the late 1980s.

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.

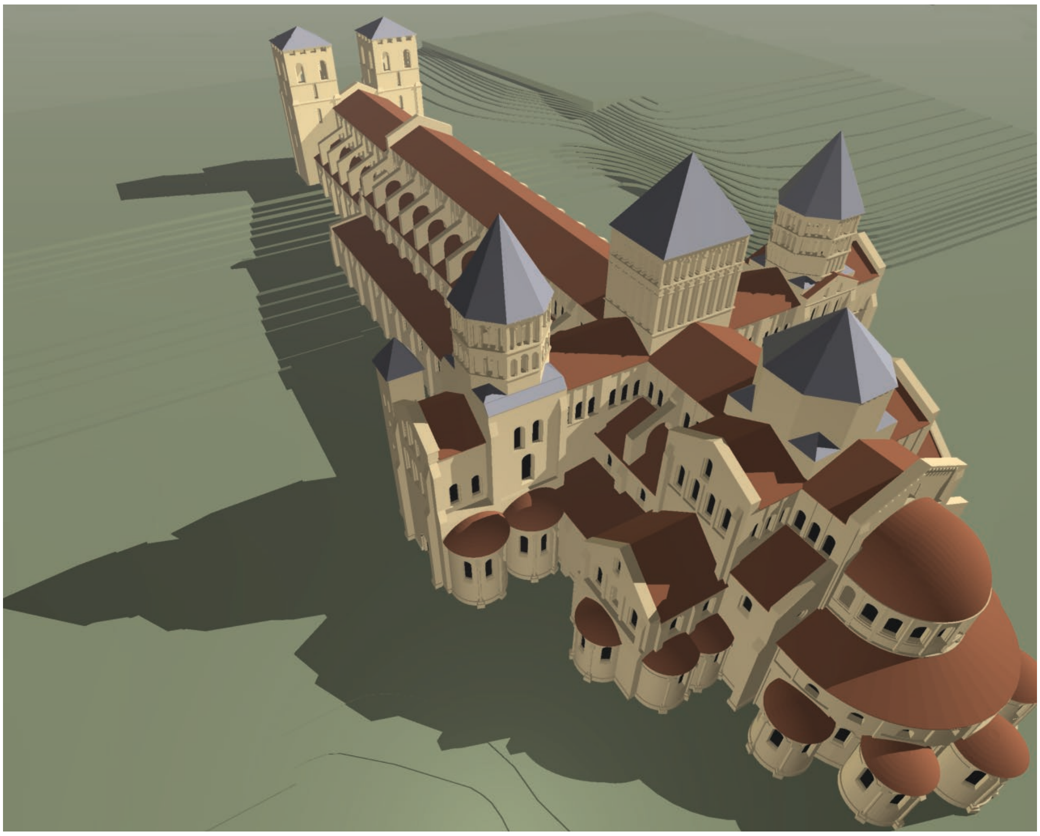


Fig. 6a 7337 individual components were merged into 320 assembly groups, which make up the complete structure of Cluny (digital reconstruction of Cluny III in 1989).

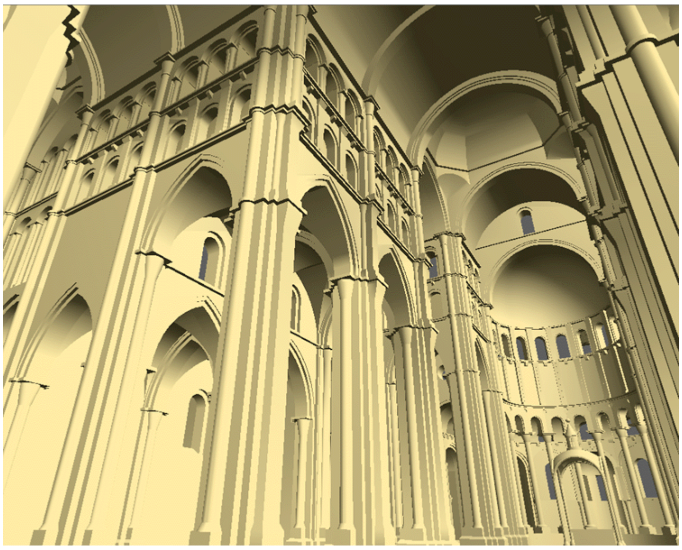


Fig. 6b View of the interior of the digitally reconstructed church Cluny III (1989).

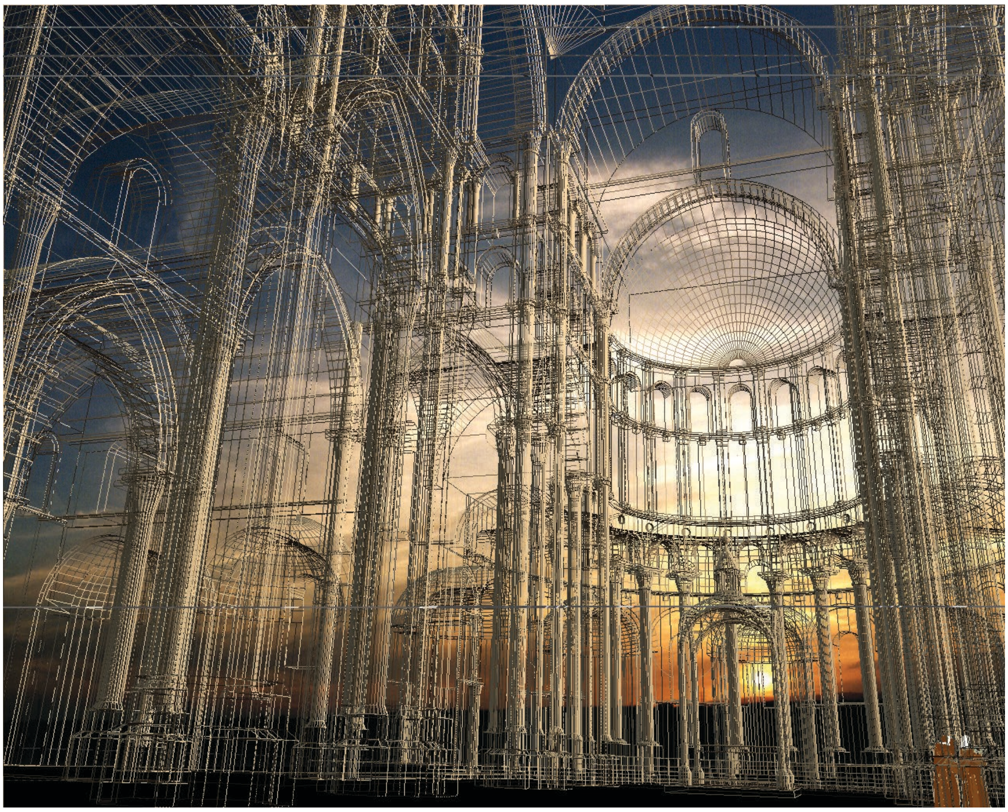


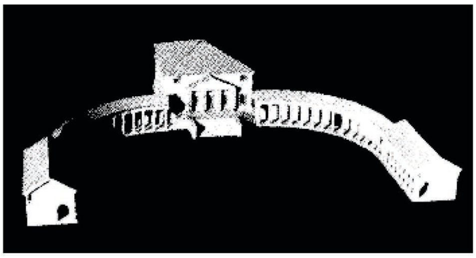
Fig. 6c Wireframe model of the digitally reconstructed church Cluny III (1989).

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]



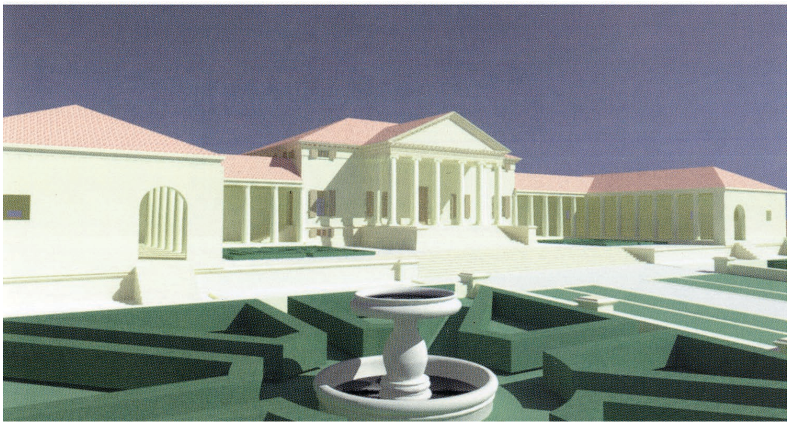


Fig. 7 Computer reconstructions of possible Palladian villas by Thomas Seebohm:
above, model of the Casa di Villa and its barchessa, first scheme (1991);
below, a different version of a Palladian villa with its geometrically laid-out garden (early 1990s).

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]

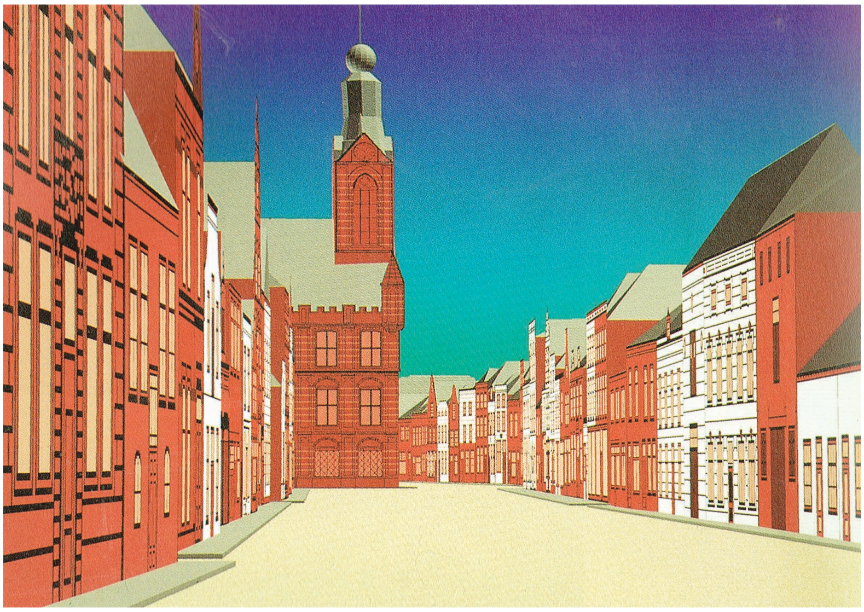


Fig. 8 Patricia Alkhoven's computer reconstruction (1993) of the city of Heusden, showing a view of the main street and Town Hall in 1943.

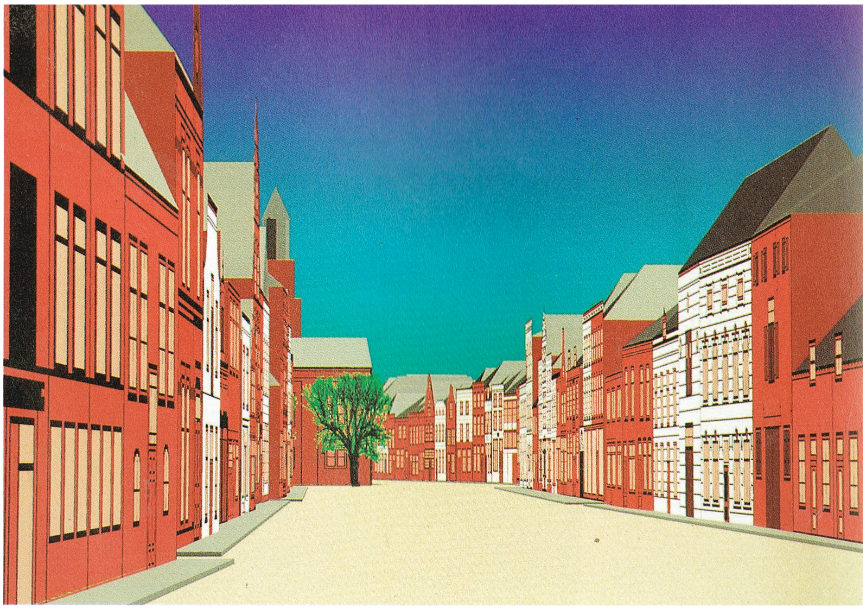


Fig. 9 Patricia Alkhoven's computer reconstruction (1993) of the city of Heusden, showing a view of the main street and Town Hall in 1990.

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]

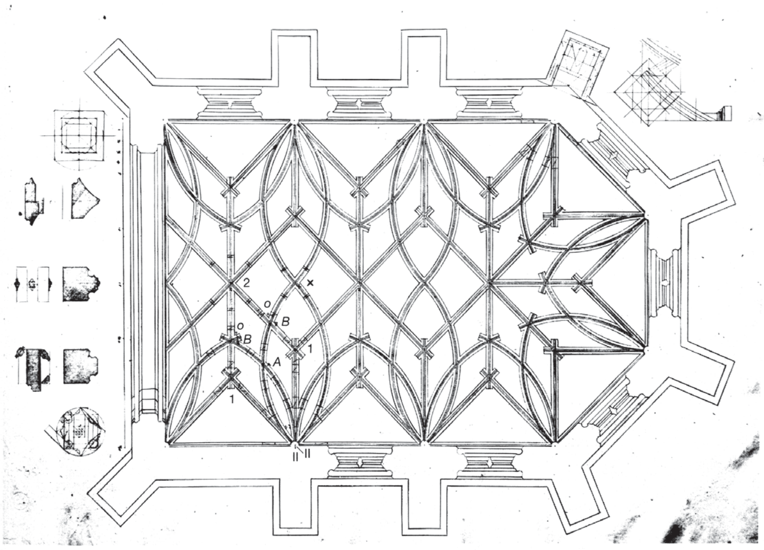


Fig. 10 Floor plan for a late Gothic church choir in the 'Stromersches Baumeisterbuch' I, end of the 16th century.

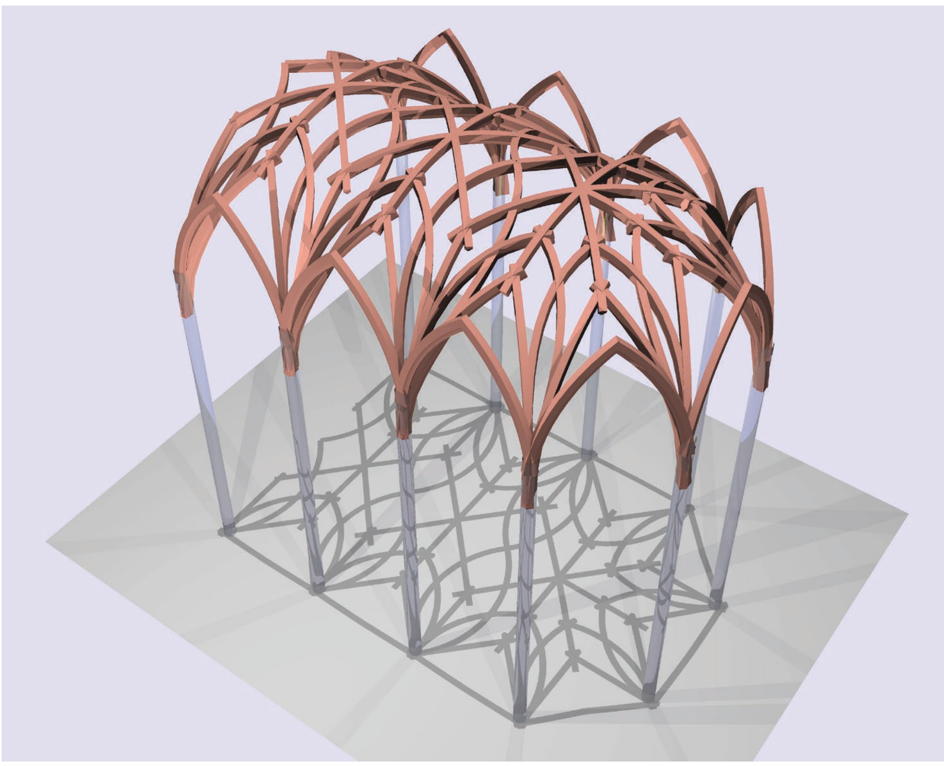


Fig. 11 Digitally reconstructed structure of a vault by Werner Müller and Norbert Quien, lit from above with parallel light. The shadow, a projection of the three-dimensional shape into the horizontal plane, is identical to the original plan (compare fig. 10), state 1991.

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]

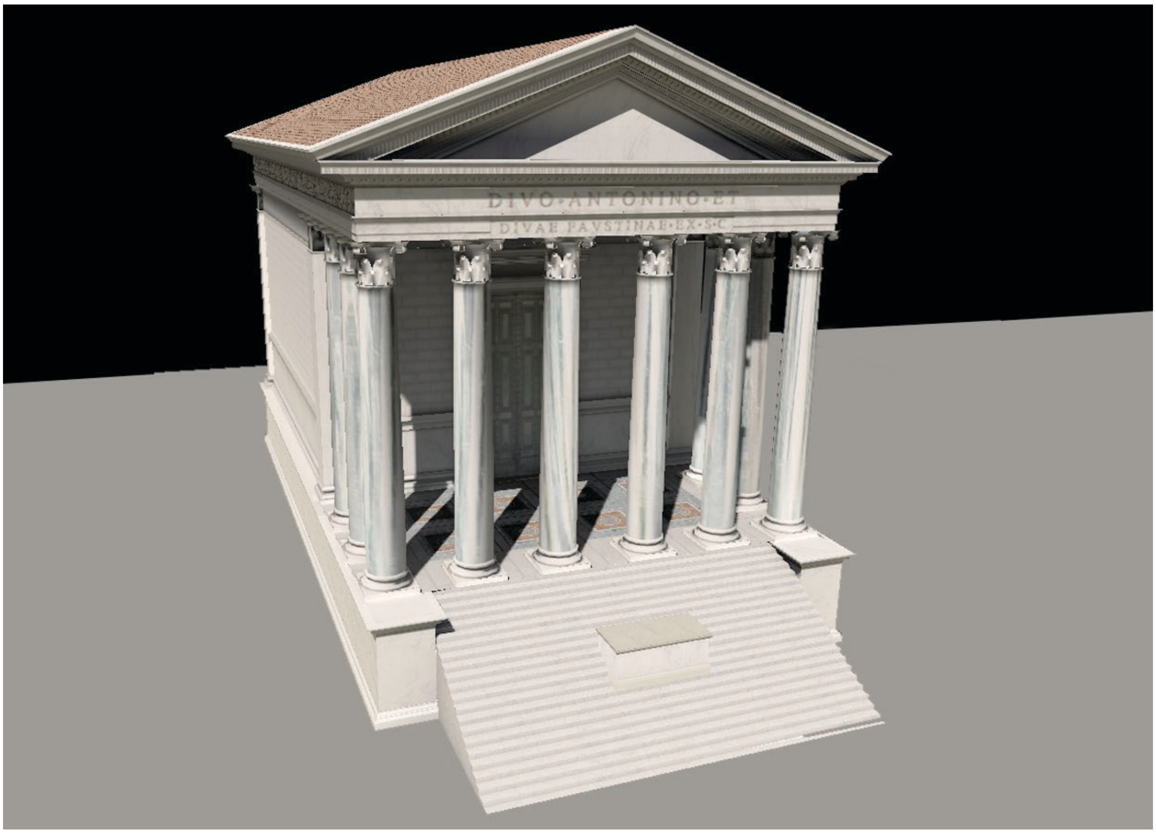


Fig. 17 Antoninus et Faustina, templum. Imperial cult temple commemorating the Emperor Antoninus Pius and his wife, Faustina. Reconstructed state: Building as first dedicated. Here: Reconstruction view. First 3D model of the *Rome Reborn* project (1996).

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).

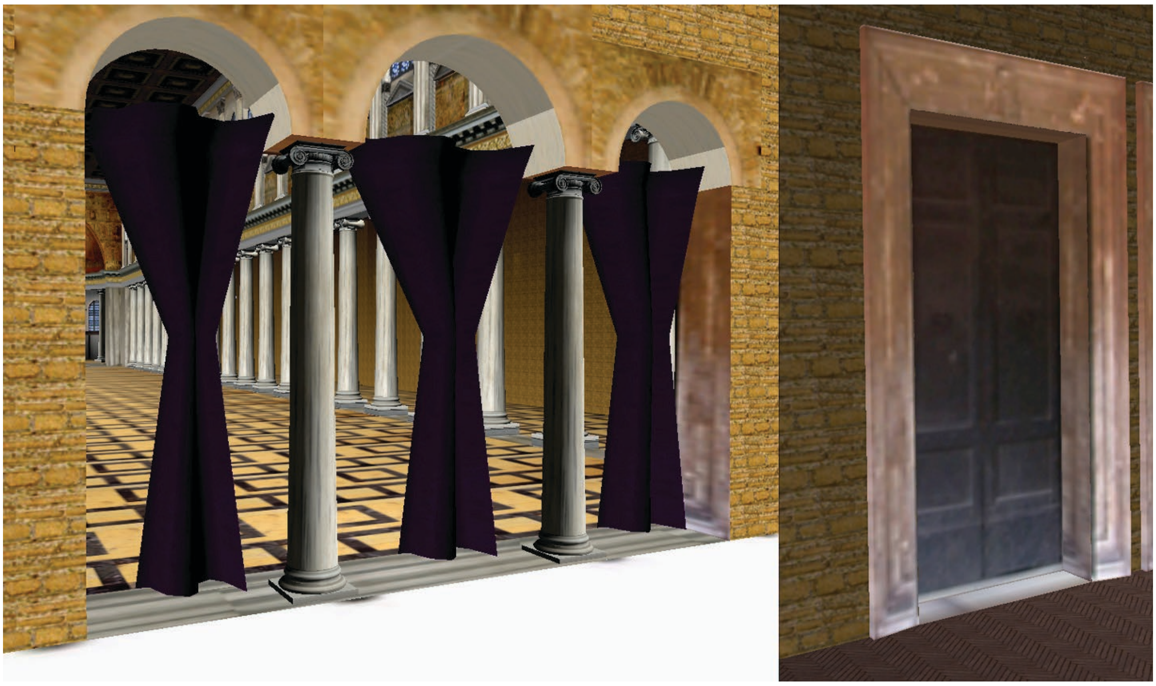


Fig. 18 Alternative reconstructions of the front entrance of the Basilica of Santa Maria Maggiore (left: curtained openings of the final version; right: doors in an earlier version), part of the *Rome Reborn* project (1996).

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).

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Virtual Palaces, Part II
Lost Palaces and their Afterlife

Virtual Reconstruction between Science and Media

Edited by
Stephan Hoppe & Stefan Breitling

With the assistance of
Heike Messemer

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