

25 Years of Virtual Reconstructions

Project Report of Department Information and Communication Technology in Architecture at Technische Universität Darmstadt

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Abstract: The virtual reconstruction of cultural heritage has a 25-year tradition at the Department of Information and Communication Technology in Architecture at the Technische Universität Darmstadt. During these years the design of three-dimensional models has changed radically. The game sector, film industry and prime time TV documentations have set standards. This has led to a great challenge for most of virtual reconstructions. These cultural projects with small budgets must deal with the expectations of clients and the public and thus there is a certain obligation to make reconstructions appear as realistic as possible. From the scientific point of view, it is clear that most of the reconstructions are based on a mixture of definite knowledge and uncertainties. Our task in the future will be to deal with these uncertainties in a graphically interesting way.

On the other hand, so called didactic models that depict reconstructed architecture in abstract form can be convincing when combined with good didactic concepts and good dramaturgy.

Over a longer period of time the presentation of virtual reconstructions involved only images - pre-calculated and in real time. A new phase is the transformation of virtual models into physical models through rapid prototyping. Thus in a way there is a comeback of physical models. In comparison to traditional models, these models have distinct advantages.

From the scientific point of view a further question will be whether virtual reconstructions should be considered a typology or a discipline of their own, they themselves becoming an object of research. In the future an emphasis of virtual reconstructions should be placed on the development of a unified methodology and comprehensive documentation. The goal will be to develop virtual research environments in the Internet and to ensure scholarly quality.

Keywords: Virtual Reconstruction, Rapid Prototyping, Virtual Research Environment, Cultural Heritage

Introduction

The department of Information and Communication Technology in Architecture (FG IKA) at the Technical University Darmstadt has accumulated nearly 25 years of experience in the field of reconstruction of World Cultural Heritage sites. Since the founding of the department many of these sites have been reconstructed and presented to a broad public (TECHNISCHE UNIVERSITÄT DARMSTAT 2013).

The basic principle of our efforts is to reconstruct buildings or other structures within the given context of politics, religion, urban development and current research results. The course of the projects is affected by cooperation with other scholars.

In our research we place emphasis on the virtual reconstruction of no longer visible buildings or other architectural structures on the one hand, and on the other on research concerning three-dimensional models as a research method, virtual research environments, transfer of knowledge and new forms of memory. The results of 25 years of research at the FG IKA are shown in a workshop report that includes a cross-section of the completed reconstruction projects and general positions concerning current developments in the transfer of knowledge as well as current research questions.

Workshop Report

The cross-section of the most important projects including our latest research project “The Cathedral in Florence” (TECHNISCHE UNIVERSITÄT DARMSTADT 2013) is organised according to special topics.

Sacral Buildings

The first topic of the cross-section is “Sacral Buildings”. The Cathedral Cluny III was reconstructed in 1989 and with this project the foundation was laid for all following projects of the department. As one of the very first digital reconstruction projects, the reconstruction of the church in Cluny III was based on the transfer of construction elements into the computer. The result was an image, fascinating at the time, of a structure that no longer exists.

One of the goals of the project “The Cathedral of Speyer” was to visualise a construction site of the 11th century. Our main focus was on the illustration of the construction process, construction methods and tools of that time. For this purpose the appearance of the cathedral of 1066 was reconstructed. In addition, the data set was used for a visual simulation of the structural modifications to the present-day cathedral in Speyer. In this way a total of eight planning versions were shown and geometrically verified from various relevant aspects.

The virtual reconstruction of the Boyana Church (fig. 1) was the appropriate medium for conveying the unique frescoes of this cultural heritage to visitors. Because of its murals this church was included in the list of Unesco world cultural monuments. However, due to the poor state of preservation, it is presently accessible to very few visitors. Thus the church and the murals were surveyed digitally and thoroughly photographed. These data were converted into a three-dimensional model in which particular attention was paid to the fashioning of the various layers of plaster and the paintings.

The project “The Construction History of St. Peter’s Basilica” illustrates the complex history of development processes and construction elements. During the course of the 350-year construction period many famous architects and artists made plans for the cathedral. For the most part they were realised only partially or not at all. The virtual reconstructions show the plans within their political and artistic contexts. A further important aspect was the transfer of the construction of the dome into three dimensions.

The reconstruction of the cathedral at Mainz completes the list of sacral buildings. The three construction phases were reconstructed on the occasion of the millennial anniversary of the Mainz cathedral. The structural state of the cathedral in the year 1000, 1239 and 1500 A.D. were shown in an abstract manner. Taking the available historical sources and the associated verified findings into consideration, the context of urban development of the given period was visualised as far as possible.



Fig. 1 – Virtual Reconstruction of the Boyana Church (Copyright: FG IKA, TU Darmstadt)

Palaces

The first example in this category, the reconstruction of the “Berlin Palace”, is highly topical today. Thirteen years ago the Berlin Palace had already been reconstructed in its splendour complete with furnishings as a highly detailed digital three-dimensional model. In this project particular focus was placed on visualising the route that would have led a visitor of that time through the portal and the famous Schlüter Courtyard to the presence of the monarch. The basis for the furnishings of the interior rooms was photographs, for the most part in black-and-white, that by means of digital technology were fused into an overall view.

The goals of the next project in this category “Dresden Royal Palace” were the visualisation of the construction phases of the palace, the reconstruction of selected rooms and the creation of a haptic model in addition to a film as a permanent exhibit in Dresden. Besides showing six selected construction phases, the Dresden Palace was visualised in the context of urban development in the year 1678. The intention of the digital reconstruction of the interior spaces of the Palace Chapel (fig. 2) and the Giants’ Hall (fig.3) was to convey to visitors the former splendour of the sites. The original furnishings are no longer visible nor can they otherwise be experienced.



Fig. 2 – Virtual reconstruction: Palace Chapel of Dresden Palace (Copyright: FG IKA, TU Darmstadt)



Fig. 3 – Virtual reconstruction: Giant's Hall of Dresden Palace (Copyright: FG IKA, TU Darmstadt)

Cultures of the World

The project “The Vatican in the High Renaissance” is the first example in this category. It became possible to experience in virtual space the rooms of the papal palace of the 16th century as they were originally furnished. The project included two key aspects. The first was to reconstruct the ideal palace of the architect, Bramante. It was never completed, soon built over and is nowadays perceptible at only a few places within the Vatican. The second was to show the palace in the contextual interrelationship of the sequences of rooms and the interaction of programme architecture and programme painting. This work was based on surveying data, photographs and written records of ceremonial routes from the 16th century.

The next in this category is the culture of the Aztecs and the virtual reconstruction of its central building, the “Templo Mayor”. The construction history shows the rebuilding process of this temple and its ritual context. Ten times during its history, the Templo Mayor has been built over again. For the first time, the individual construction steps were shown three-dimensionally on the basis of current research as well as the possible causes of these occurrences. The data set is available to scholars for the further development of the model and the incorporation of latest data.

The project “The Construction History of the Kremlin” was a great challenge because plans from various Russian archives had to be brought together. The virtual reconstruction shows the 850-year construction history of Kremlin and different structural states, for example the wooden phase, the red Kremlin, the white Kremlin and individual buildings (fig. 4).

The project “The Imperial Tombs of Xi’an” - an example from Chinese culture – consisted of two large projects: the imperial grave of the first emperor Qin Shihuangdi and the imperial grave of the Tang emperor Taizong at Zhaoling. This reconstruction was produced for the exhibition at the Art and Exhibition Hall of the



Fig. 4 – Virtual reconstruction: The construction History of Kremlin (Copyright: FG IKA, TU Darmstadt)

Federal Republic of Germany in Bonn in which the results of fifteen years of German-Chinese co-operation in the area of protection of cultural goods were presented to the public. Through virtual reconstruction the exhibits were placed in their overall context and thus conveyed their cultural importance. The three-

dimensional model fused knowledge of the cultural region around Xi'an and led to new research findings concerning China's cultural heritage.

Immaterial Culture of Remembrance

The category "The Immaterial Culture of Remembrance" is a focal point in Darmstadt. Since 1994 more than 25 synagogues have been visualised in the computer. On the basis of plans, drawings, photographs and reports from eyewitnesses the project visualises the cultural loss and calls to mind the importance of the architectural heritage of the buildings (Fig. 5,6). In addition, the Synagogue Internet Archive was initiated as an active contribution to immaterial remembrance. The development of exhibits for memorial sites is also an important aspect (GRELLERT 2007).



Fig. 5,6 – Virtual reconstruction: Synagogue in Plauen (Copyright: FG IKA, TU Darmstadt)

Urban Structures

One of the important projects in this category is "The Virtual Reconstruction of Ephesus in the Byzantine Period" based on research activities of the Austrian Archaeological Institute. The goal of this large project was to illuminate the history of the city and important individual buildings. The urban development of Ephesus, beginning with the Greek period and continuing through Roman times up to the Byzantine epoch, was visualised, as well as the complex system of aqueducts required for supplying the city with water. The reconstructed individual buildings included the Slope House, the Byzantine Palace, the Celsus Library and St. Paul's Grotto. The research results so far available in archives were brought together in a three-dimensional model, so that a cohesive picture of the city of Ephesus arose as the basis for further research.

Monasteries

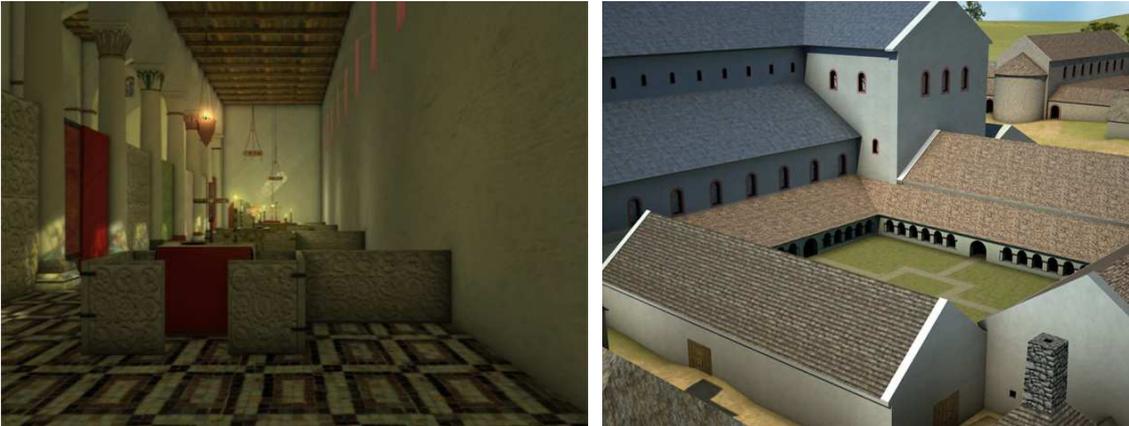


Fig. 7,8 – Virtual reconstruction: Benedictine Monastery Plan, Church (Copyright: FG IKA, TU Darmstadt)

An example for this group is the project “The Benedictine Monastery Plan” which interpreted the plan as an organisational guideline and the red lines on the plan as a clear measure of the interior space of the building independent of the construction material. The interiors and exteriors of important monastery buildings were reconstructed on this basis. A virtual library of furnishings was developed as a basis for further research projects (fig. 7).

Icons of Architecture

The project “The Crystal Palace” is of importance in this category and will be discussed in the following. The Crystal Palace is a unique building that is important in the history of structural engineering. The direct transfer of the construction elements into a three-dimensional model led to new information concerning the functioning of this construction system that was novel for its time. The joining of the elements, the structural calculations and the spatial effect, trend-setting then, were the focus of the project.

The History of the Construction of the Florentine Cathedral

The newest research project of the FG IKA “The History of the Construction of the Florentine Cathedral” completes the cross-section of our projects (fig. 8,9). The project places emphasis on two aspects in particular, the description of the planning history of the façade and the construction of the dome. The state of knowledge concerning the buildings on the site that existed prior to the present-day cathedral is not yet very advanced. Thus a special, cautious type of presentation was chosen in order to make the uncertainties clearly recognisable. The result of this interdisciplinary and international research project, a 3D-stereo projection, was shown at the Art and Exhibition Hall of the Federal Republic of Germany. The cathedral was presented to a broad public as an important monument in the history of architecture within the context of a huge exhibition dealing with the city of Florence. The digital data set is available for further research.



Fig. 9 – Virtual reconstruction: Florentine Cathedral (Copyright: FG IKA, TU Darmstadt)



Fig. 10 – Virtual reconstruction: Florentine Cathedral (Copyright: FG IKA, TU Darmstadt)

General positions

Looking back at these years of experience we would like to point out some general positions about virtual reconstructions. Three points will be covered:

1. Design
2. Presentation
3. Research

Design

The design of three-dimensional models has changed radically in the past two decades. The game sector, movie industry and prime time TV documentations have set the standards, the more realistic the better. 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. There is the risk that an older look also means that the message, that is the information, is old.

But no reconstruction is based on sources that have no gaps. In realistic models it is inherent in the system that solid knowledge and gaps must be similarly presented. The more realistic the models become, the more realistically the facts that one does not know for certain must be depicted. Regardless of how good the sources are and how extensive the findings are, the models all look the same.

This means that gaps must be dealt with in a responsible way and I hope that different aesthetical visual languages can be developed to show the uncertainties.

On the other hand, we also encourage the use of so called didactic models that show reconstructed architecture in abstract form. Such models can be convincing when used with good didactic concepts dramaturgy.

In the scientific context it is necessary that solid knowledge and derived reconstruction should be comprehensible. However, this need not be automatically evident in the presentation. It is not alone the decision of the person doing the reconstruction or of the scientific advisor, but often that of the client. There is a broad spectrum of presentation forms.

Presentation

Digital data sets offer various outputs. Digitality is thus one of the most important features. A new phase was the transformation of virtual models into physical models through rapid prototyping. Thus in a way there is a comeback of physical models and in this way presentation can be divided into images (pre-calculation and real time) on one hand and rapid prototyping models on the other.

Images

Both pre-calculation and real time presentations have their advantages, real time presentations by way of direct links with information to the architecture and to self explore a building or city.

The advantage of pre-calculated films and images lies in the clear pre-definition of the content to be shown. Therefore real time applications are normally more expensive and intended for use only by individuals. The ability of a given person to navigate determines the success and the resulting acquisition of knowledge. The goal of a museum is to present one hundred percent of the available knowledge to all its visitors; the best medium for this is a film.

In the future augmented reality applications for mobile devices will gain importance. It is not certain whether other special forms of presentation such as 3D stereo will prevail for a long time. We are still awaiting convincing 3D holographic presentations. Perhaps when they arrive, they will be as important in the transformation of digital data sets as rapid prototyping models are currently.

Physical Models - Rapid Prototyping

Rapid prototyping technologies allow for overnight production of physical models from digital data sets. These technologies were originally used for industrial prototype production. Eight years ago the FG IKA transferred this technology to the area of virtual reconstructions. Below we will discuss some of the fundamental insights in terms of technology that have resulted from this experience (ARCHITECTURA VIRTUALIS 2013).

Typology of Use

The typology of use of these haptic models is divided into three categories: mono, parallel and hybrid.

“Mono” indicates that the basis is digital but the exhibit involves only the physical model (fig. 10).

“Parallel” indicates a parallel presentation of both the virtual and physical model. An example is the virtual reconstruction of the Dresden Palace. In this case both a film representation and a haptic model were prepared. Both forms of output result from the same digital model.



Fig. 11 – Rapid Prototyping Model of Dresden 1678 (Copyright: FG IKA, TU Darmstadt)

“Hybrid” indicates that the advantages of digital and haptic models can be shown in one exhibit (fig. 11).

Hybrid models are normally urban models or models of landscapes. By means of a projection it is possible to illuminate certain areas of a haptic model and simultaneously display the background information on a projection screen. This is possible because, as is the case with parallel exhibits, projection and model are derived from a single digital data set.

The animations that are projected onto these models lead to new kinds of installations with new aesthetic appeal and new forms for transferring knowledge. Special landscape models have also been developed in Darmstadt that are displayed by means of animated maps. For example, human migration, the alterations in European political borders or an animation of the frontlines during World War I have been dealt with.

Materials

Since the beginning of rapid prototyping technology, the IKA Department has been addressing the concept of materials for haptic models. New technical developments in this area have been rigorously tracked and investigated with respect to practicability; the properties of materials and costs have been researched in depth. The range of materials extends from plaster, sand, plastic – varnished or not – to ceramics and metal. It is just this material, metal, that is currently in the focus of research with respect to practicability for exhibit pieces.



Fig. 12 – Hybrid Model (Copyright: Architectura Virtualis GmbH)

Special Advantages

Some advantages of rapid prototyping will be pointed out in the following summary.

1. In many cases rapid prototyping models are more economical.
2. It is possible to achieve a very high degree of detail, even in small objects.
3. Inexpensive production of duplicates.
4. Combination of physical with virtual models, hybrid models as described above.

5. The possibility for visitors to touch models. Because the original is stored in the computer, damage caused by visitors is not very problematical. Reproducing the damaged exhibits is not expensive.
6. Production of directly coloured models is possible.
7. In a scientific context rapid prototyping technology offers immense opportunities. It is possible to first develop everything in the computer together with various experts and then produce the model.
8. There is also the possibility of updating the models economically. Should changes be required as a result of research findings, individual areas can be newly virtually constructed, reproduced or replaced.

Research

The use of virtual reconstruction has expanded (MÜNSTER 2011). Initially research resulted in the visualisation of lost architecture in a new form.

In the future there will be more and more virtual research environments in which reconstructed architecture is a reservoir for research and its content (HERMON 2012). Its links will be discovered and used by scholars worldwide via Internet.

Virtual reconstruction will also be a tool for the simulation and better understanding of technical and social processes (BAUMEIER 2010). The challenge will be to convey these processes and their uncertainties in an aesthetically appealing way in words and images and to find a practicable solution for documentation of the reconstruction process (PFARR 2010). Our vision is documentation in 5D.

And finally, especially long-term archiving and backup are a further challenge. Data sets from the first decade of virtual reconstruction are barely legible today. Further knowledge has been lost due to personnel changes or antiquated software or hardware.

All of the research topics mentioned above are focal points of current research projects in our department. According to the UNESCO Charta (UNESCO 2003), virtual reconstructions are also a part of digital cultural heritage. The knowledge contained in them must be stored in a sustainable manner.

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Imprint:

Proceedings of the 18th International Conference on Cultural Heritage and New Technologies 2013 (CHNT 18, 2013)

Vienna 2014

<http://www.chnt.at/proceedings-chnt-18/>

ISBN 978-3-200-03676-5

Editor/Publisher: Museen der Stadt Wien – Stadtarchäologie

Editorial Team: Wolfgang Börner, Susanne Uhlirz

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