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).
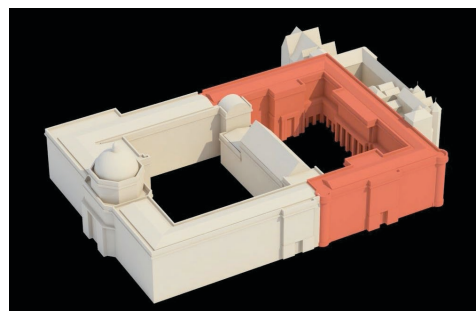

Fig. 1 Dresden castle, rendering 2011.

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.

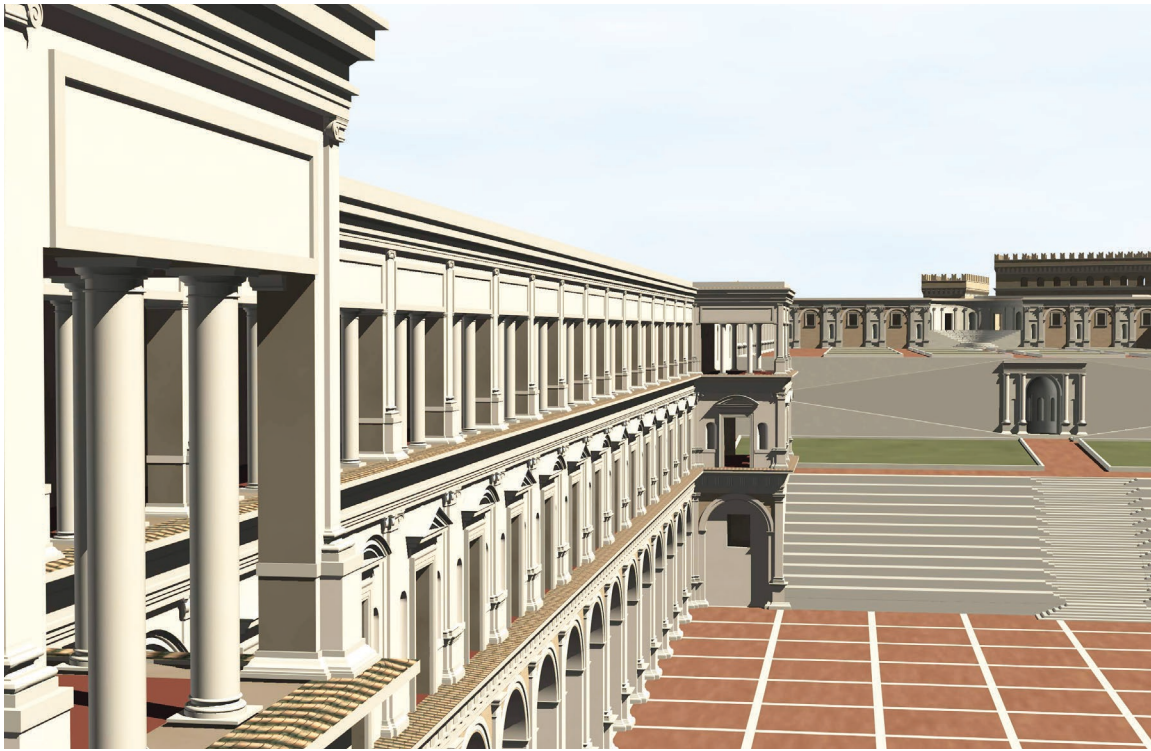Fig. 5 Schlüter court, Berlin castle, rendering 2011.

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.
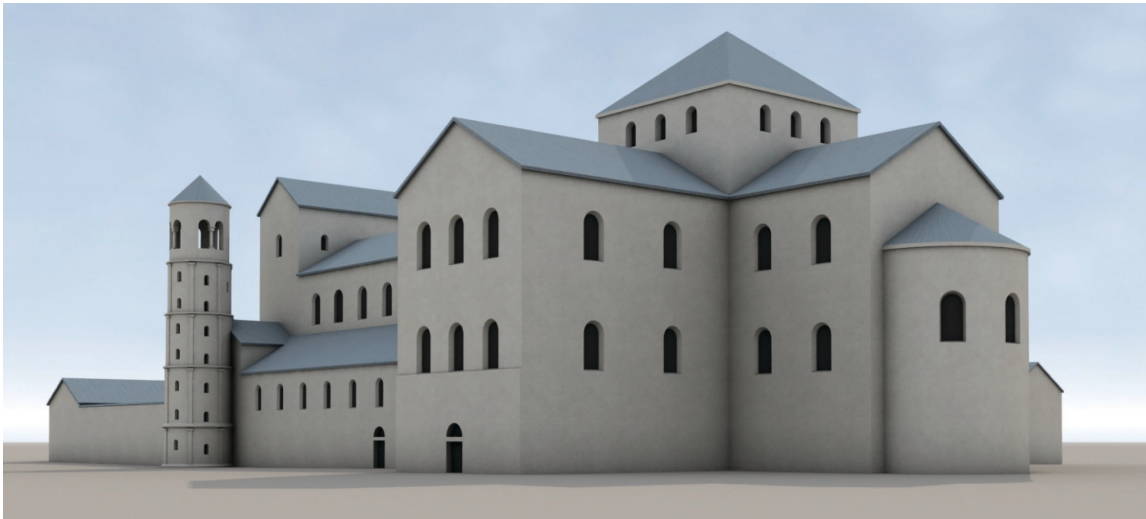

Fig. 13 Different solutions for the Romanesque phase of Mainz cathedral, renderings 2009.
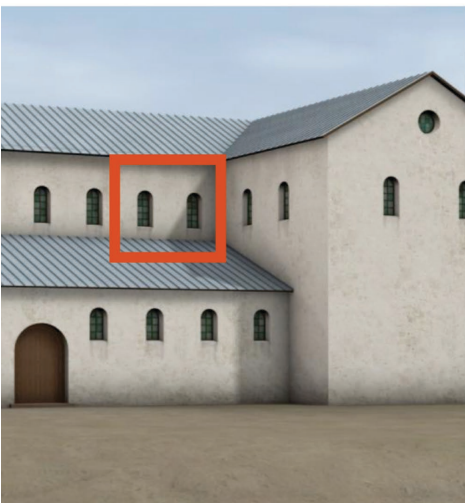
Fig. 14 Various sources for the virtual reconstruction of the Carolingian imperial palace at Frankfurt, renderings 2008.

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.
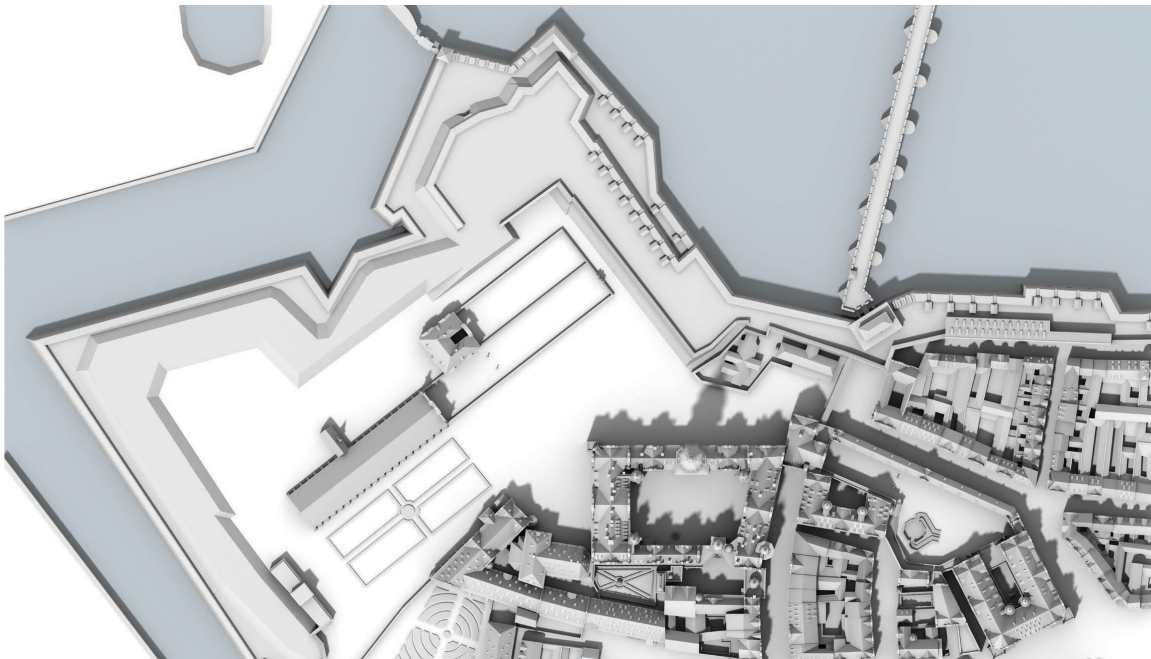

Fig. 15 Digital template for the haptical model, complete sector of representation, rendering 2011.
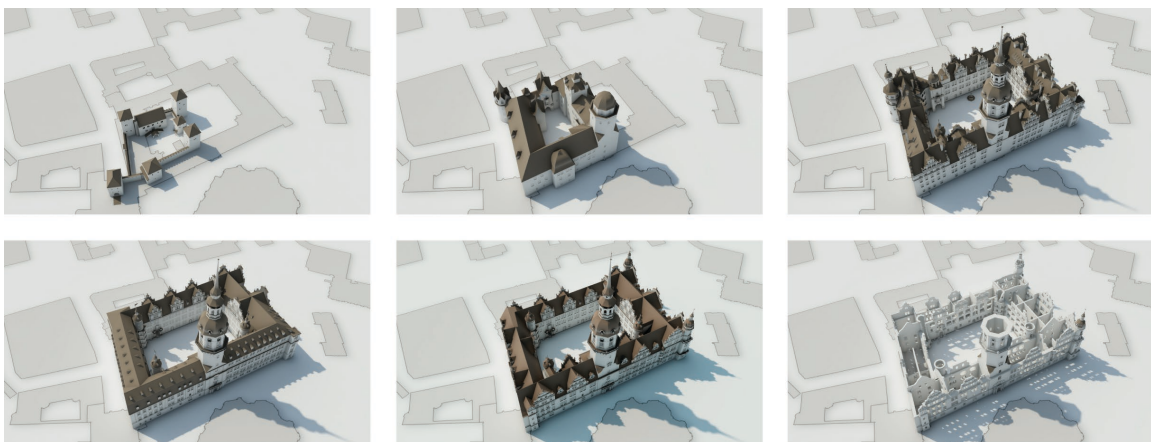

Fig. 16 Six building phases of the castle: 13th century, 1535, 1678, 1768, around 1900, 1945, rendering 2011.

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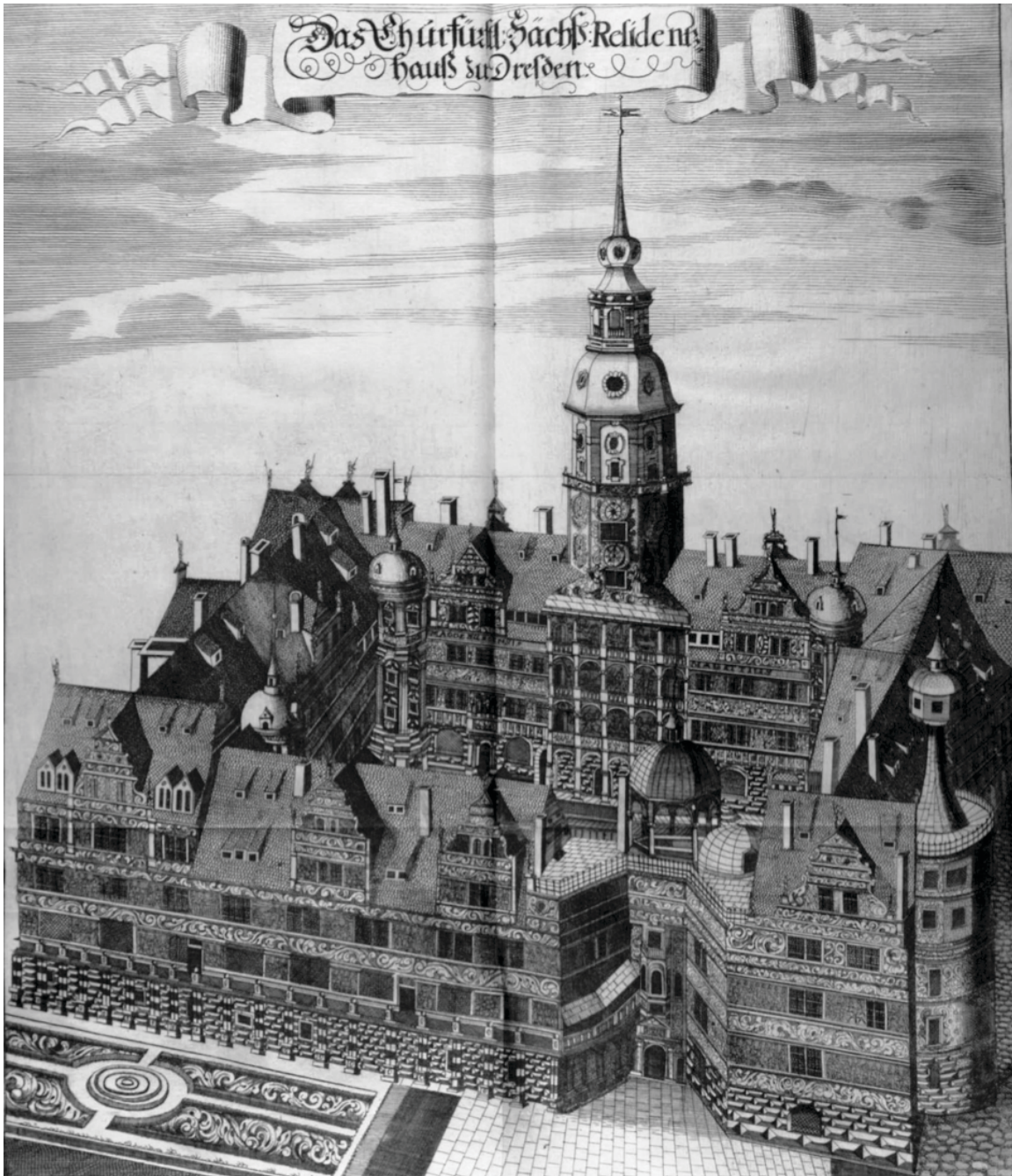
Fig. 18 The Castle from a bird´s eye perspective. Copperplate by Anton Weck, *Der Chur-Fürstlichen Sächsischen weitberuffenen Residentz- und Haupt-Vestung Dresden Beschreib- und Vorstellung*, Nuremberg 1680.

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.

Motiv	Beschreibung	Autor	Datierung	Jahr		Technik	Maße	Sammlung	Signatur	Inst.	Dateiname
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 Kanzleihaus	Grundriss	P. Buchne	um1591	1591		Tusche			GG	LfD	u_sho_1586_062_b, u_sho_1591_178
Der Stallhof unter Christian I.	Ansicht Langer Gang bis Fassade zum Jüdenhof		1586	1586							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-Aufzug aus dem Raths zu Dresden Schieß-haußе 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=50000	LfD	u_itd_1756_002_s
Sophienkirche mit Umgebung			um 1750	1750		farbig		Dresden 1/215	M10.cl.Bl.5 (M=50D01.7	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	perspek. 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, 2B	C 4280	Kuka	u_sge_1743_099
Plan et Elevation des Ecurie Roiales à Dresde	Fassade des Stallhofgebäudes zum Jüdenhof nach dem 1. Umbau 1729/30 durch Pöppelmann	Glässer, A	Nach 173	1730		Kupferstich	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.
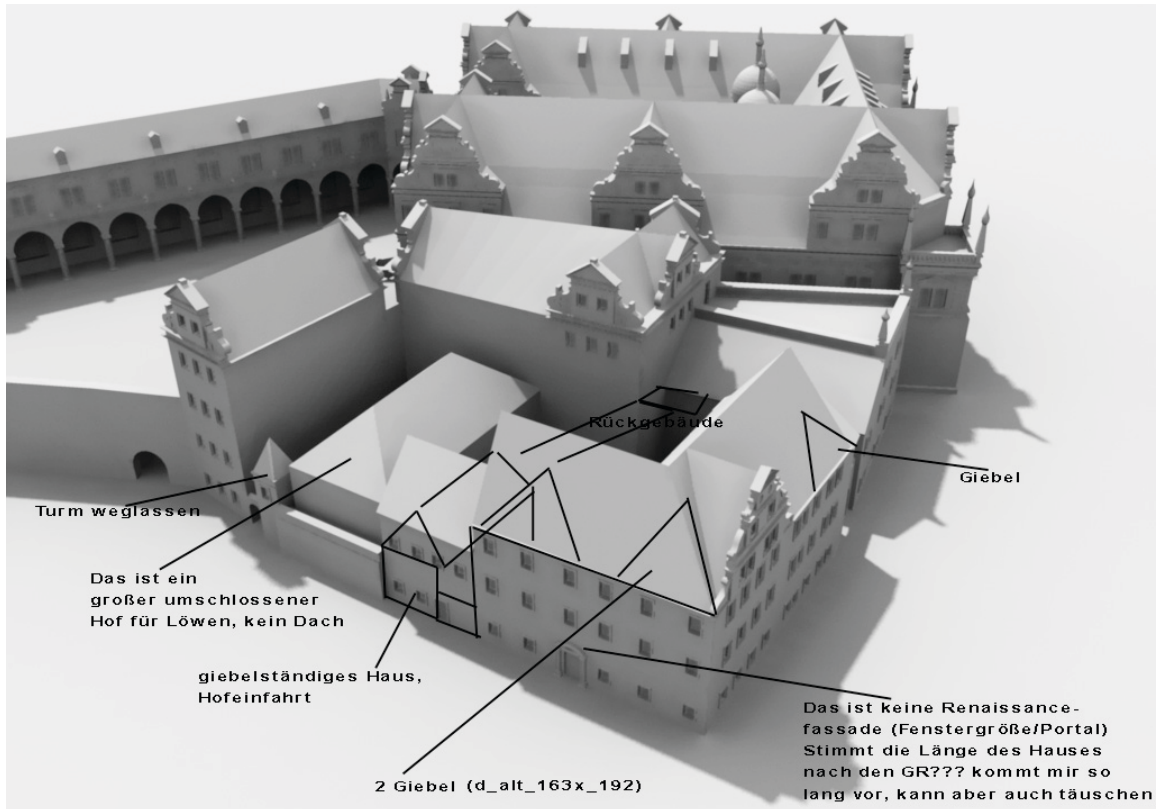
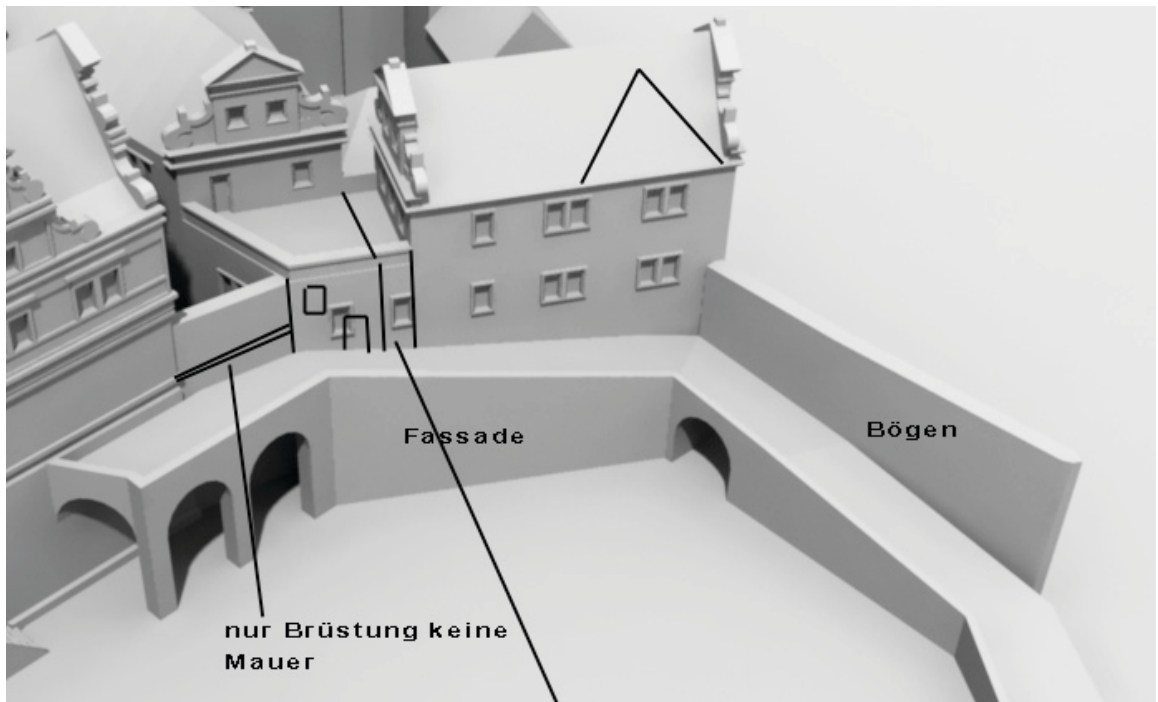Fig. 20 Proposed corrections during the work process, screenshot 2010.

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.
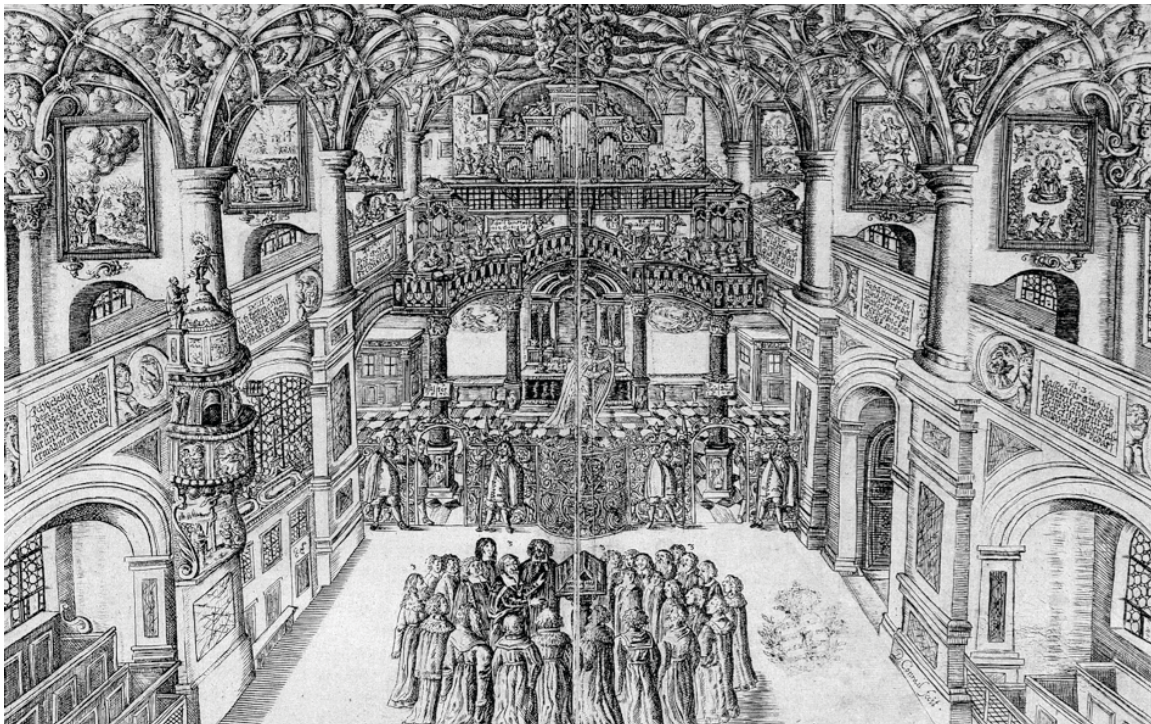

Fig. 22 Interior view of the castle's chapel. Copperplate by David Conrad, 1676.

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.
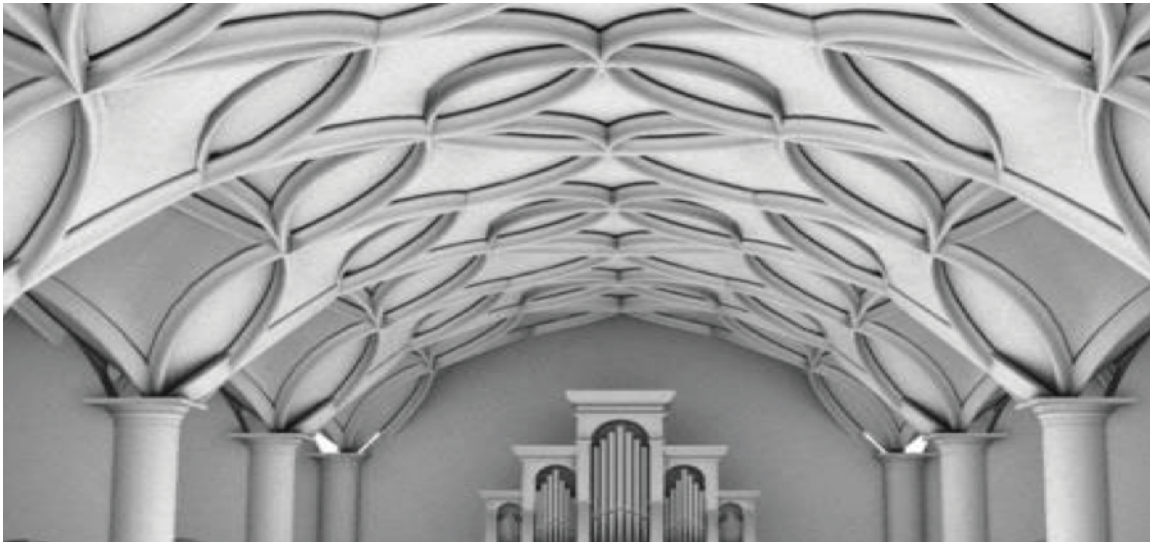

Fig. 23 and 24 Detail from the virtual reconstruction of the chapel, without the sculptures at the vault (top) and final state, screenshot and rendering 2011.

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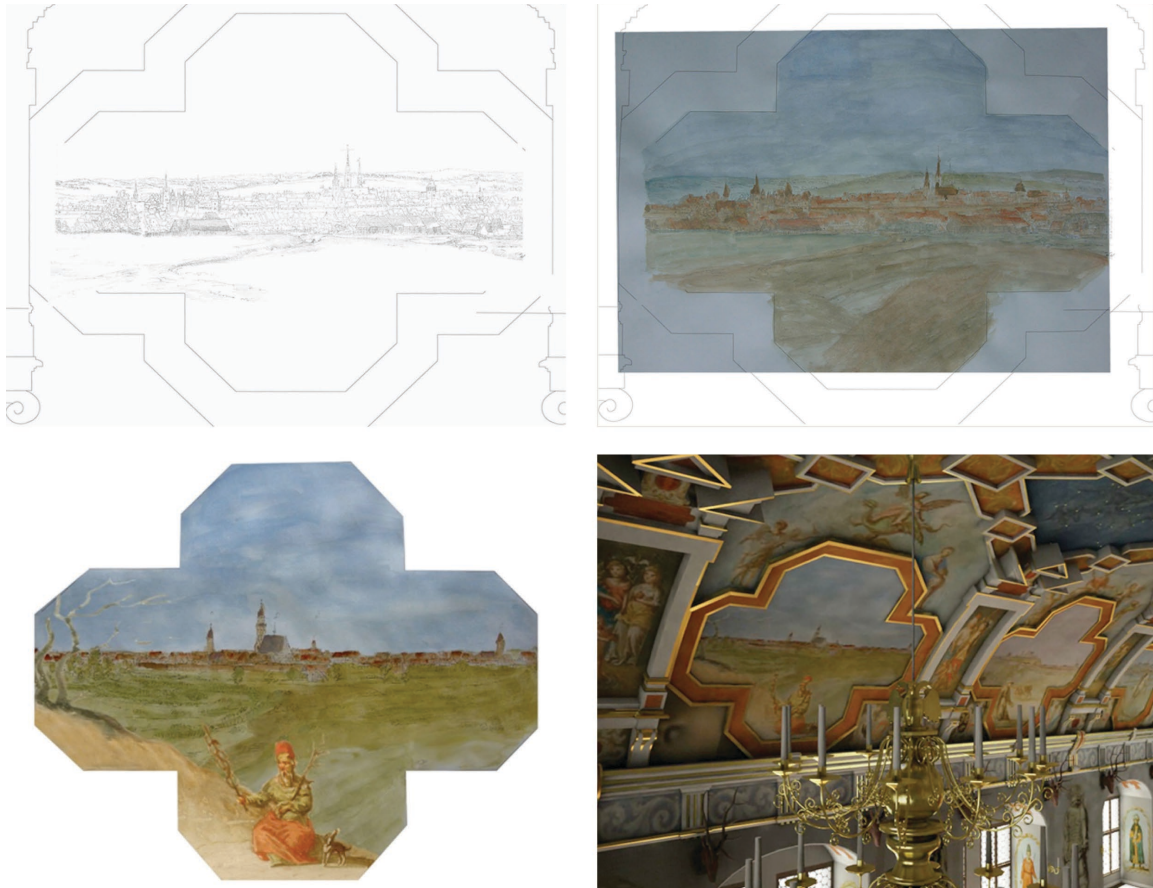
Fig. 28 Designing process of the cityscapes in the hall of giants for the virtual model.

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).
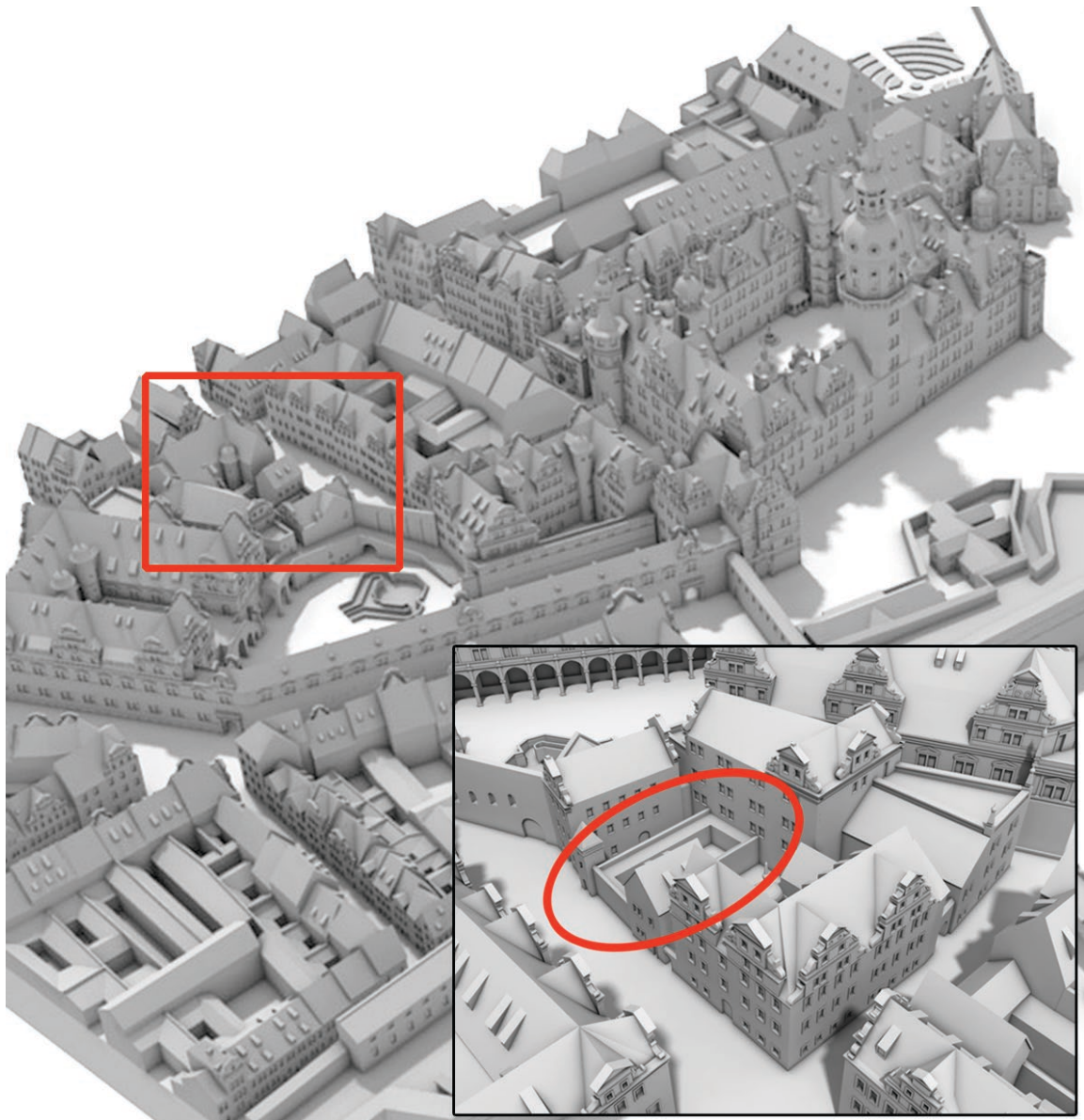

Fig. 31 Detail of the digital template for the haptic model with the so-called 'Löwenhaus' (Lion House), screenshot 2010.

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.
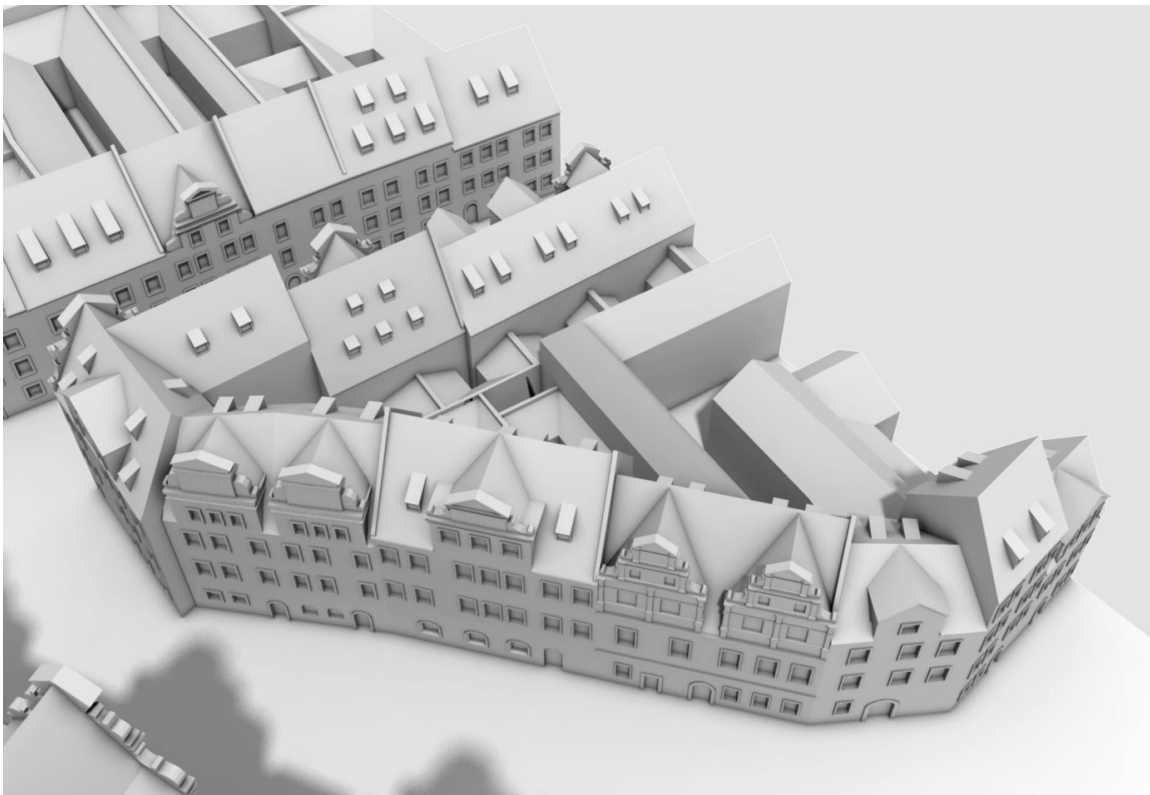

Fig. 32 Detail of the digital template for the haptic model, houses at the Neumarkt
with the abstract courtyards, screenshot 2010.

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).

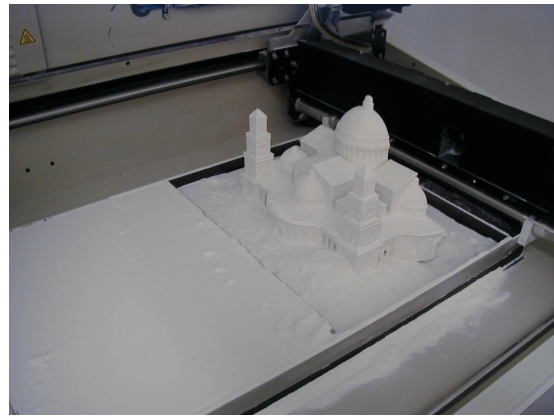Fig. 33 Process 3D printing, 2005.

Fig. 34 Printed model, 2005.

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

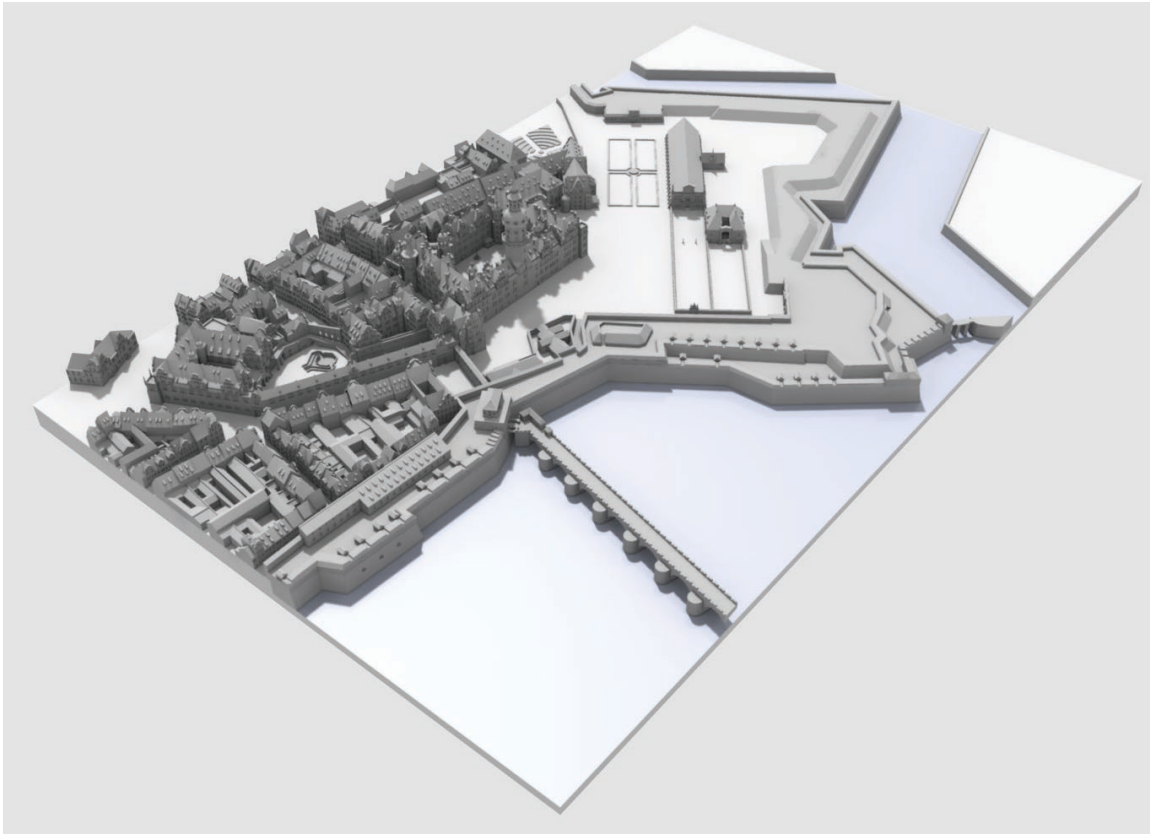

Fig. 36 Rapid prototyping model, 2005.

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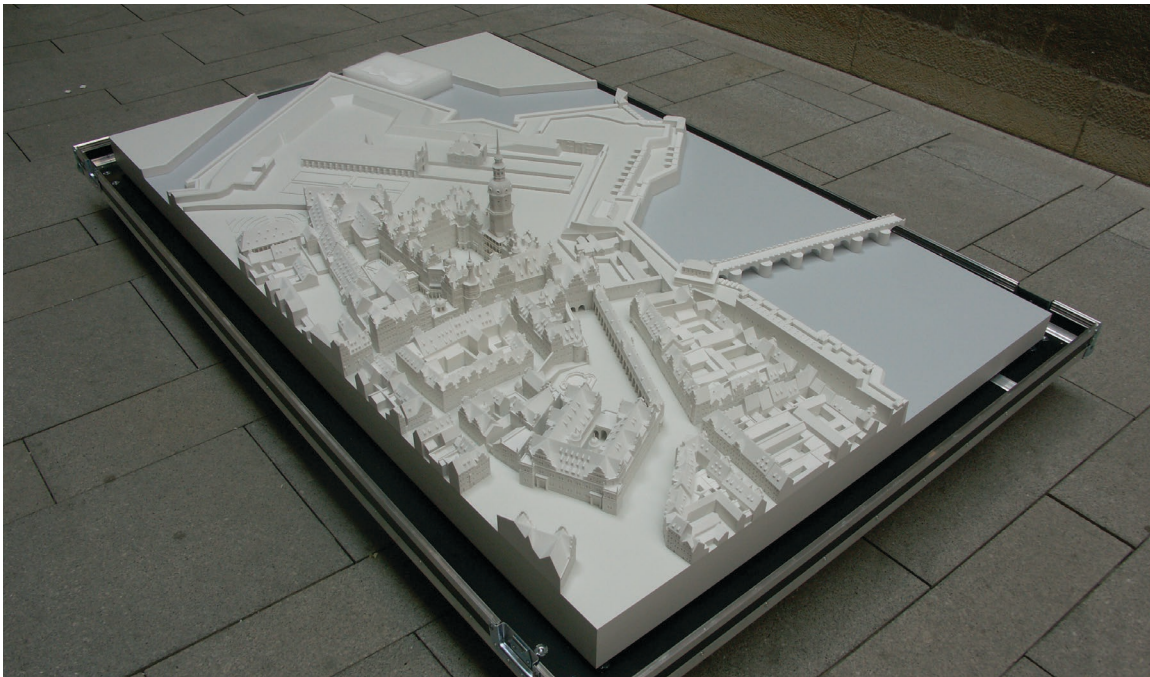

Fig. 38 Haptic city model of the Dresden castle and its spatial surroundings in 1678, 2011.

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.

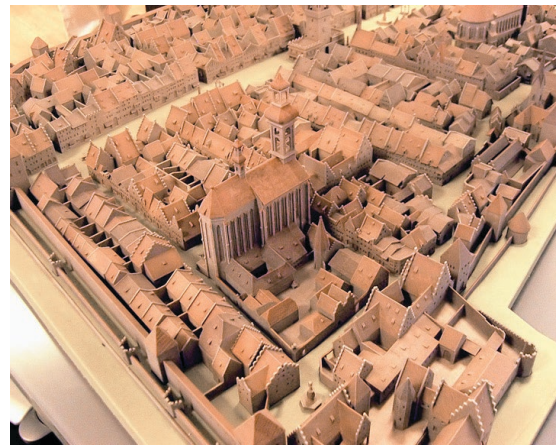Fig. 41 Exhibit 'Medieval Cities', 2006.

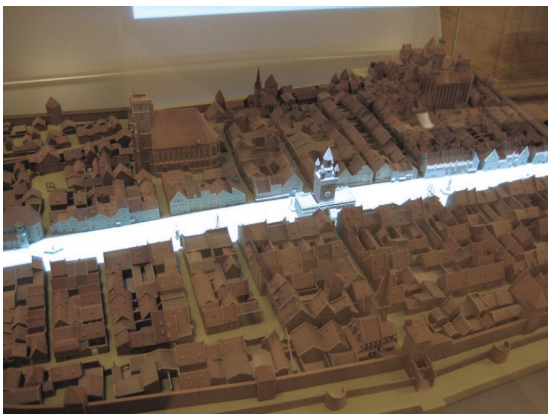Fig. 42 Rapid prototyping city model, 2006.

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.

[16] Mock, Johann Samuel, Verleihung des Hosenbandordens an Kurfürst Johann Georg IV. im Dresdner Schloß 1693, Overall view and Partial view. Staatliche Kunstsammlungen Dresden, Kupferstichkabinett, Dresden.

[17] Dilich, Wilhelm. Riesensaal, n. 29, Ceiling design. Hauptstaatsarchiv, Dresden.

[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.