IMAGINATIONS
REVUE D'ETUDES INTERCULTURELLES DE L'IMAGE ▪ JOURNAL OF CROSS-CULTURAL IMAGE STUDIES

IMAGINATIONS:
JOURNAL OF CROSS-CULTURAL IMAGE STUDIES |
REVUE D'ÉTUDES INTERCULTURELLES DE
L'IMAGE

Publication details, including open access policy and instructions for contributors:
https://imaginationsjournal.ca

Open Issue
Editors: Brent Bellamy, Margot Mellet

Image credit: Tile graffiti on the "Karstadt" department store (Salzstraße) in Münster, North Rhine-Westphalia, Germany. By Dietmar Rabich, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=109359687

To cite this article:
Lengyel, Dominik, and Catherine Toulouse. "The Design in the Visualization of Uncertainty, Abstract Modelling and Virtual Photography." *Imaginations: Journal of Cross-Cultural Image Studies* vol. 15, no. 1, 2024, pp. 145-204, doi: https://doi.org/10.17742/IMAGE29710.

To link to this article: https://doi.org/10.17742/IMAGE29710

THE DESIGN IN THE VISUALIZATION OF UNCERTAINTY, ABSTRACT MODELLING AND VIRTUAL PHOTOGRAPHY

DOMINIK LENGYEL
CATHERINE TOULOUSE

INTRODUCTION

This paper aims to present a visual language that directly depicts the imagination of the sciences, which is capable of reproducing architectural statements in the humanities as unadulteratedly as possible even if they are formulated in an uncertain way because they are based on uncertain knowledge (Fig. 1). In this way, the architectural statements can be communicated visually and also have a reflexive effect on the humanities. Because these images have a direct effect on the imagination, they are simultaneously a means of communication and research. The paper is aimed at an assumed readership with a general interest in science and design without any particular subject-specific background. Since the journal is based in the academic discipline of art history, the authors attempt to address the specifics of the design disciplines in some places, where there is occasionally a need for clarification of procedures and working methods. The authors are architects themselves, so that the transdisciplinary presentation explains many things that are self-evident in architecture, in order to awaken an understanding for these things in general, on the one hand, but above all an interest in interdisciplinary work.

Fig. 1 Cologne Cathedral around 1320 CE

REFERENCE

Images can have different purposes and appear in completely different forms. The relevant purposes in this context are information and inspiration, whereby suggestion also plays a major role, and the relevant forms here are those in the intermediate space between the image of physical reality—the common photograph (Fig. 2)—and the highly abstract diagram—the pictogram of an escape route, for example. Purpose and form are therefore two dimensions that may not be comparable, but which frame the area where the visual language presented here operates.

The visual language presented here has developed out of the discipline of architecture, if a disciplinary origin can be claimed at all for interdisciplinary approaches. However, the origin is significant insofar as architecture fundamentally has an effect on the public, which is characterized, among other things, by being intended to apply in general language, while the terminologies used have different meanings in the different disciplines. Strictly speaking, this can lead to conflicts in meaning, depending on the direction from which the term is understood. For this reason, in the following the authors will try to use terms in a generally understandable way. In some excep-

Fig. 2 Circus Maximus, Rome

tions, however, it seems unavoidable to the authors to take up certain specifications, also in order to avoid misunderstandings. For example, the term "physical reality" refers to that reality which is generally considered to be our own immediate perception, that is without the aid of technical means, but also without the effort of constructing any theoretical concepts. In order to understand the visual language, the authors also do not consider it necessary to further define which reality is meant or even how many realities exist in total (Fig. 3).

FORMS OF IMAGES

The now most common form of images is that which depicts physical reality. Images can always be classified according to their degree of realism, and this is independent of whether they are perceived in physical reality or, for example, in virtual reality, that is, through 3D glasses. The common language formulation for this form of appearance is to describe it as looking real. Although every form of representation that looked just as real as was technically possible was described in this way, this classification remains

Fig. 3 Naga Royal City Exposition, Egyptian Museum, Munich

significant because it places a meaning in the foreground of the description of the image, namely to be truthful, that is, to reproduce reality unadulterated. The term "documentary" fits into this pattern

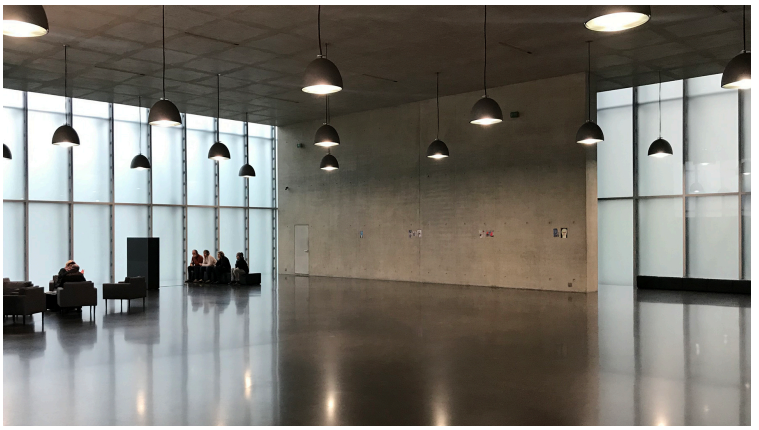

Fig. 4 Kunsthaus Bregenz, Austria

of meaning. Especially in visual communication towards the general public, this authenticity of whatever kind plays a major role (Fig. 4).

The authenticity of an image has a direct effect on its subjective plausibility. Images that are considered genuine are often interpreted as genuine without further questioning. Things shown in such images are assumed to be real and true (Fig. 5). There is no other explanation for the controversy surrounding manipulated photos or even images calculated by artificial intelligence. The fact that such calculated results are called photos in the general press shows the confusion in the perception and interpretation of those images that are readily assumed to be real. Apart from the importance of the classical photographic composition of point of view, angle of view, and direction of view, not to mention lighting and exposure, even before the artificial calculation of photo-like images in every apparatus there was a change in what was visible in front of the lens, be it in the form of granularity due to the chemical sensitivity of the film to digital processing and alleged optimization of the electrical signals on digital sensors.

Realness is thus perceived as absolute—images are either real or not—while the relation of the visual appearance of an image to phys-

Fig. 5 T-Cell gas to power transformer

ical reality in any other form is readily perceived as gradual and also accepted. Oil paintings, which are generally described as realistic, are readily received as illustrations of physical reality, whereas this is not the case with paintings of cubism, for example. The term "abstract" is used for this form of representation, and the authors will continue to operate with this term merely in order to distance themselves from the form of physical reality. In the expanded concept of reality, on the other hand, such a distinction would be much more difficult, since it could be claimed that the reality of the abstract artist is precisely that which is visible in abstract painting (Fig. 6).

Even if the first impression of realness is particularly pronounced in paintings, the same basically applies to every other form of image generation, from drawings to collages. The question of authenticity, of the relationship to physical reality, always dominates the perception. Especially in the case of drawings, however, there is already an important differentiation, namely the separation between geometry and materiality. Drawings are allowed to be genuine in a certain way, namely to reproduce the geometry, that is the spatial structure, close to reality, to be genuine in this respect, while materiality can be completely disregarded, not only in the general sense but even in the case

Fig. 6 The Gulf of Marseilles Seen from L'Estaque, by Paul Cézanne, around 1885

of line drawings. This form of abstraction of materiality alone will be of importance in the following (Fig. 7).

In the case of fully abstract images such as diagrams, which obviously do not depict physical reality, the question of authenticity becomes obsolete and is replaced by the question of relevance, of meaning in relation to what is indirectly represented. Symbols such as the indication of the escape direction by the use of generally understandable signs certainly refer to elements of physical reality, but in a highly abstracted way. The figure running in the direction of a rectangle, that is, the person running towards an opening, symbolizes the way to an exit enabling escape. Much of what is depicted is learned, yet such symbols strive to be universally understood (Peirce, p. 205).

So nevertheless there is indeed a reference to physical reality, only this is in need of interpretation and also requires a higher mental processing load. If we look at the perhaps most common form of diagram in architecture, the floor plan drawing, it represents a diagram

Fig. 7 View through the Herculaneum Gate, Pompeii, by Giovanni Battista Piranesi, 1778

that has an unmistakable reference to the geometry of the building, while neither the appearance as a whole nor a large part of its elements correspond to their appearance in physical reality (Fig. 8). Rather, it is the spatial relationships of the elements to each other, merely in terms of their horizontal positioning, that are depicted in this diagram. Still, floor plan drawings are accepted and commonly used as relevant, if not indispensable, components of the representation of architecture. The reason for these forms of representations lies in their purpose of use. This becomes especially clear in the case of the floor plan, which in adapted form also represents the basis for its construction during the building process.

PURPOSES OF IMAGES

This brings the purpose of the image into focus. The level of meaning spanned here ranges from information to inspiration, and here, too, it is primarily a matter of the space in between. If a scope for interpretation will always be given, it imposes

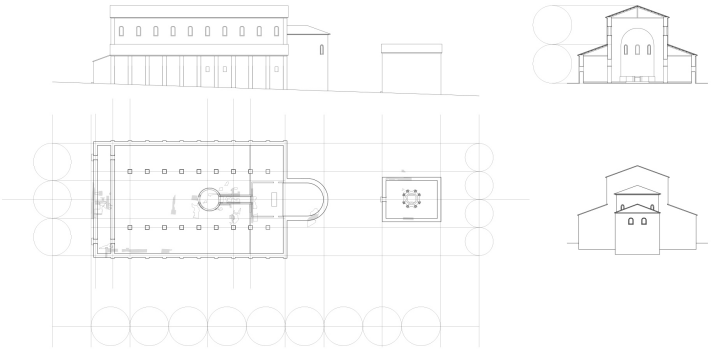

Fig. 8 Cologne Cathedral's predecessor of the 6th to 7th century CE

itself sometimes more and sometimes less, depending on the form of representation. The least obvious impulse to reflection, and thus inspiration, arises naturally from the depiction of physical reality, the invocatory character of which is already made difficult by the attribute of realness that the image, whose form at first glance, as explained above, is given, and can arise solely from the content depicted. The more abstract a picture, on the other hand, the more interpretation necessarily becomes involved (Fig. 9). But here, too, it is ultimately a question of habit and the unambiguousness of the signs (Arnheim, pp. 134–138) that result in highly abstract images, such as the image of the figure walking in the direction of a rectangle described above, nevertheless being unambiguously interpreted in terms of their meaning. Of course, this does not exclude misinterpretations, as the similarity of the symbols for elevators and washrooms show.

The communication of information via images is perhaps the most common purpose, even if one assumes that the countless snapshots that populate social networks also convey a sense of life via the information about where one is with whom and what activity one is engaged in. The genre of documentary illustration, or photo doc-

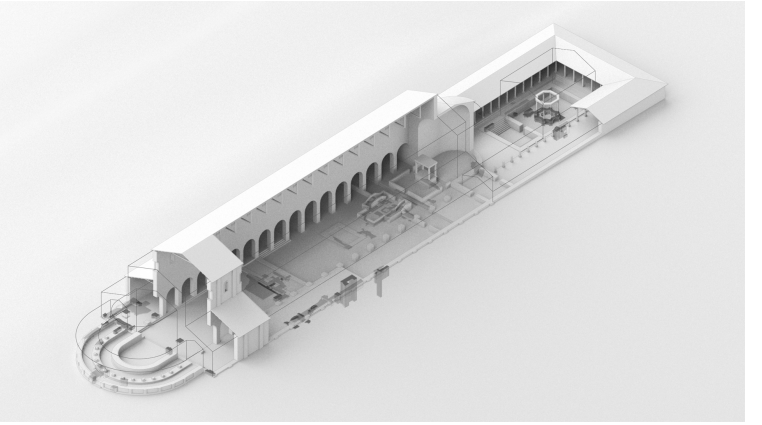

Fig. 9 Cologne Cathedral's predecessor of the 7th to 8th century CE

umentation since the expansion of photography, already aptly describes this intention. Nevertheless, and here then lies the concept of quality of the design level of photography, there are also considerable differences in the alleged documentary photography which do not concern the technical implementation, but already the level of design. In this way, however, a photograph designed as a documentary can be considered to fall into the realm of art. However, this is in no way an attempt to define art as such (Reinhard, p. 68) or to sharply divide photography into documentation and art. Rather, it is a matter of affirming a tendency, namely that photography, even if it intends to document, may communicate itself as a composed image or as something commonly referred to as a snapshot. The composed image, however, pursues the enhancement of the message to be conveyed through the means of image composition (Fig. 10).

Thus, the primary goal of diagrams is to point out facts as directly as possible, that is, to inform about matters. Also, diagrams can be at various levels of design, but here the general view is directed even more to the easiest possible extraction of the desired information, whereas the level of design is given much less weight (Fig. 11). The visualization of quantity ratios in diagrams, called pie charts, is un-

Fig. 10 Piazza St. Ignazio, Rome, Francesco Borromini

questionably informative, provided that the adjacent areas can be distinguished with a high contrast and that a legend is provided, because it informs visually about portions, that is fractions, quotients, ratios, relations. Many complex relationships, such as the proportions of some fractions to each other, are in some cases less directly readable, and also the placement of the individual components at the top, side, or bottom of the diagram may induce further connotations, but essentially the representation is objective and unambiguous.

Halfway between an image that serves purely to inform and an image that merely serves to inspire, if it is possible to separate the two so clearly, is the deliberately suggestive image, presupposing information that tendentiously suggests a thought process that goes well beyond the actual content. Diagrams in particular are often designed to suggest conclusions. Bar charts, for example, stacked components of a quantity distribution, which at the same time show the change of the sum of their individual parts over time, like to place the most strongly changing part directly on the time axis, so that all the components seem to be changing, even if the smaller parts are basically only shifting, while their size actually remains unchanged. The bor-

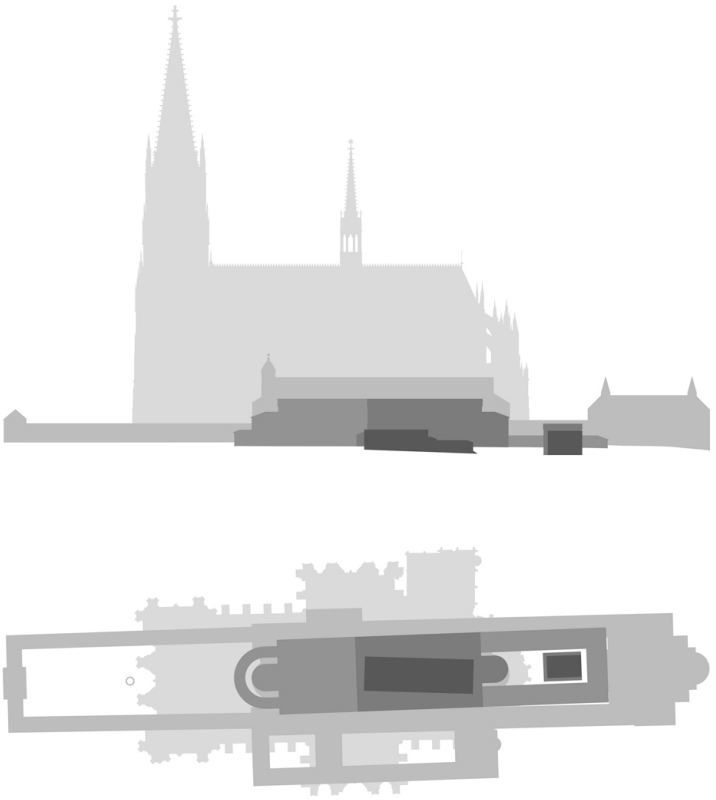

Fig. 11 Cologne Cathedral and its predecessors from the 1st century CE until today

der to manipulative representation is fluid here, intended or unintended.

Finally, inspiration is a function of an image that can naturally arise from any image, and in this respect the listing of these three purposes of an image is not to be understood as comprehensive and conclusive, not even a selective ranking. With regard to the pictorial language presented here, however, inspiration plays an important role, since these pictures suggest that we ought to think further. Inspiration always arises from images when the viewer is motivated to

take more from what is perceived than is objectively represented. In the case of a real photo, this can be anything—the planning of a city greening at the sight of a street intersection, or the same idea at the sight of a diagram showing biodiversity in the context of industrial agriculture. However, inspiration can also arise to a particular extent when a picture suggests matters in such a way that it is obvious that there is something invisible behind it, for example in the form of silhouettes. Shadows are so clearly reduced images of their more complex origins that the first question that arises when looking at a shadow is what it is from (Fig. 12). Not without reason do shadow figures offer an extremely popular game with perception and the simplicity of deceiving it. Plato's Allegory of the Cave likewise uses the image of the shadow to paraphrase the phenomenon of human cognition (Fig. 13).

Here, however, a distinction can be made between implicit and explicit inspiration. Here, too, it is merely an attempt to comprehend the relationship conceptually; a distinction could also be made between intended and unintended inspiration. But even this is not un-

Fig. 12 Ancient city of Messene, Peloponnese, Greece

Fig. 13 Antrum Platonicum, Jan Saenredam after Cornelis van Haarlem, 1604

ambiguous. The relation between inspiring sense impression and generated inspiration is always manifold, and also depends on something in between, namely that of the unconscious inspiration, which nevertheless determines the active participation. The following juxtaposition shall illustrate this.

The visual perception of unadulterated nature, for example, and to remain in the image of the image, an ordinary, casual, that is at least not consciously composed photograph of a forest, can inspire bionic constructions (Fig. 14). At least this form of inspiration from the side of the sensory stimulus, the forest, considered, is unintentional and probably also implicit, since the explicit perception of forest presumably concerns the tree, while even firewood and relaxation are interpretations which, however, do not necessarily cause any inspiration.

It is different with artifacts. These can be designed in such a way that they almost provoke inspiration, all the more so the more abstract they are. The *Black Square* by Kasimir Malevich is perhaps the most

Fig. 14 Hollow Oak Tree, Fontainebleau, by Gustave Le Gray, 1855–57

extreme example of this. The square, like the forest, holds a multitude of interpretive possibilities, but the square takes a more offensive approach here. It practically demands an interpretation; it is not least its declaration of being an artwork that is clarifying in this respect. But even this need not include the intention of the author of the artifact, and in the context of the visual language presented here, it is irrelevant what the author himself intended. Rather, what is decisive is the quality of the artifact, which, including all mediation parameters as well as its positioning as a work of art in a museum, induces an active engagement that may result in inspiration, but which depends primarily on the viewer and is therefore perhaps intentional, but in any case implicit (Fig. 15). This phenomenon can thus also be explained by the viewer's expectations, perhaps his or her previous education, that is, the retrievable readiness to immediately question the ambiguous for its implicit potential for inspiration. The emp-

ty black square, simply found, offers so little explicit information, merely colour, proportion, and absolute measure, presumably always in that order, provided one faces not its photograph but the original; otherwise, only colour and proportion remain. At almost every point in the contemplation of images, the contemplation of the contemplation of images, as well as the creation of images, one encounters the limits and traps of verbal terminologies. One only has to think of the fact that black is not even called a colour in contexts other than the common language, which can likewise give rise to inspiration. If black was not a colour, what would the title say about the square?

THE VISUALISATION OF HYPOTHESES

The description of forms and purposes of images above is, as mentioned, not intended to be complete or to serve as evidence. Perception is much too subjective for that, even if there are statistically ascertainable effects that can be researched and

Fig. 15 Erwin Heerich, Museum Insel Hombroich

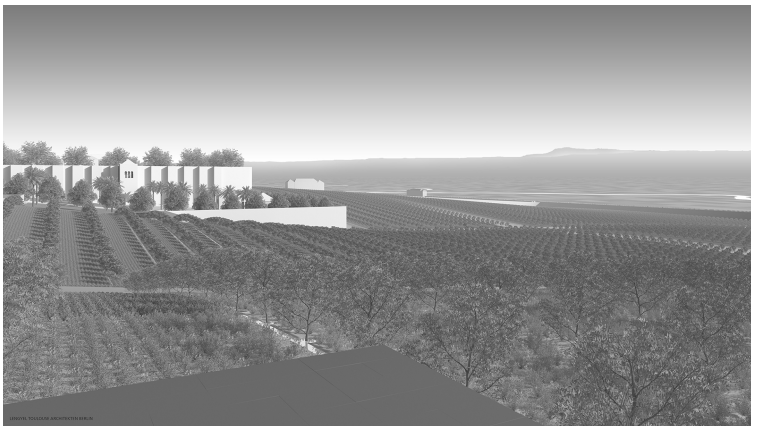

Fig. 16 Orchard in the Umayyad palace city of Medina Azahara in present-day Andalusia in the 10th century CE

proven strictly according to the rules of psychology (Glaser, et al., 2016, pp. 1135–1151). It is only to point out those aspects of the images of the visual language presented here, in order to be able to understand why the images look the way they do. Basically, the images are offers to draw more from the scientific content they represent than from the verbal description alone, both for the viewer and for the creator of this content. The visual language is thus an offer in both directions (Fig. 16).

The objective of the visual language presented here is, as already mentioned at the beginning, the visualization of hypotheses from the humanities of archaeology, historical building research, and art history in a way that combines a liability in spatial composition of architectural components with the greatest possible openness in terms of uncertain knowledge (Glaser, et al., 2022, pp. 1097–1131). What is thus almost always excluded is the actual appearance, as is generally suggested when reconstructions are referred to. To achieve this objective, traditional sub-disciplines from architecture and related design disciplines are combined to make use of experience in design itself on the one hand and tradition in perception on the other, and

this with the purpose of directing perception to the actual matter rather than to the form of representation. For all the deviation from the depiction of physical reality, which is thus as inevitable as it is in need of explanation, the viewer should nevertheless engage as directly as possible with what is being represented. The two sub-disciplines therefore originate not only from the pre-digital, but in part even from the pre-industrial era, namely abstract model making in the design phase and photography in the course of documentation. One reason for this, among others, is the ephemeral nature of design trends in the still relatively new medium of the digital image (Locher, et al., pp. 9–12). The recourse to pre-digital design traditions is intended to prolong the lifespan of visual artifacts (Fig. 17).

Abstract model making is a timeless characteristic of architectural modelling. Several-thousand-year-old Egyptian funerary objects show extremely reduced buildings, obvious abstractions of buildings of physical reality. Wooden models of the Renaissance, such as that of the Cathedral of St. Peter and Paul in the painting by Domenico Cresti da Passignano, in which Michelangelo presents his design to Pope Pius the IV, show simplified geometry without materiality. Clearly, the painting demonstrates that this simplified model representation received attention and even resulted in the realization of the building. Cork models also reproduced a variety of buildings without reference to actual materiality, simply through their simplified geometry. Likewise, and with even less material impression, plaster models were for a long time the standard in the communication of architectural as well as urban planning (Fig. 18). The visual tradition interprets such models without hesitation as reduced, that is, abstract, architectural representations that provide information about exactly what is recognizable, namely the geometry. Nevertheless, the work is part of the current discourse on digital architecture (Hirschberg, et al., pp. 285–302).

The method for achieving this goal is thus the combination of two traditional disciplines. However, it is necessary to take into account some peculiarities of this new content, because it is not about the construction of buildings. In a figurative sense, a direct assignment of the involved sizes and people is possible; nevertheless, the involve-

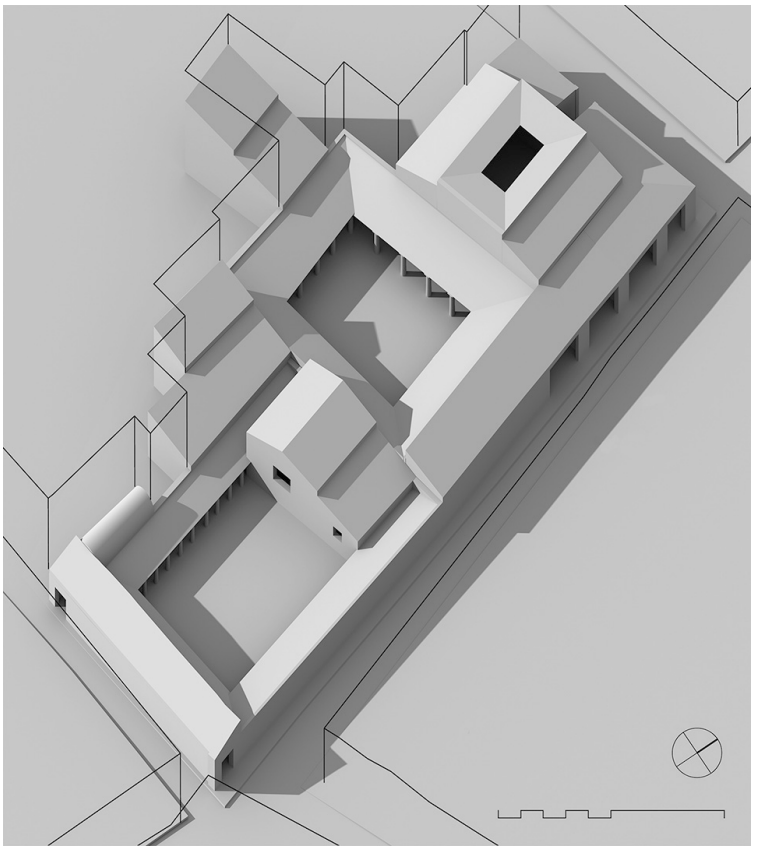

Fig. 17 Republican Baths, Pompeii

ment of the same is not quite the same as in the traditional construction project.

ABSTRACT MODEL MAKING

Model building in the design phase of architecture serves both the designing architect as well as the client as a tool in the concretization of the general, often rough idea about the building to be created, up to its realization. In the course of

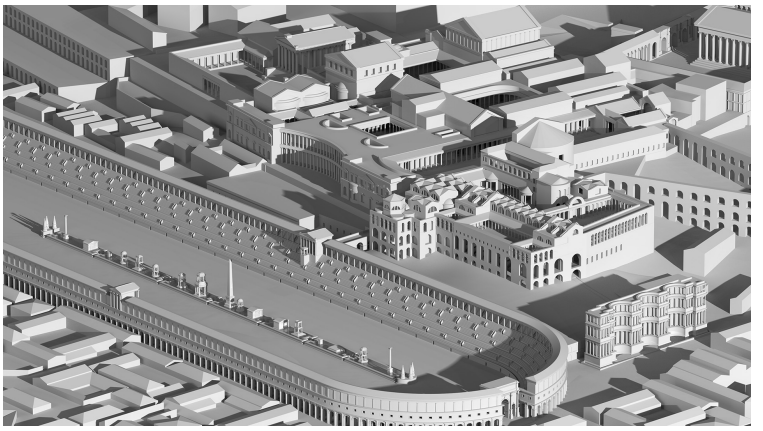

Fig. 18 Palatine Palaces in the time of Emperor Maxentius, Rome

the planning process, more and more decisions are made, often also revised, so that the models in the different design phases increasingly resemble the physical reality up to the stage of the mockup—a section of the building to be realized in the original scale with the original materials—with only the construction process not corresponding to the later realization. Thus, while the model becomes more and more condensed from the abstract to the concrete, it accompanies and guides the design process. But it always aims at its realization. This is the main difference to the visualization of hypotheses. For while in the design process decisions have not yet been made (Fig. 19), because first the rough concept is agreed upon, the knowledge of the humanities sets limits to concretization (Fig. 20). In the openness up to this moment, both processes—the planning of architecture as well as the visualization of hypotheses—still contain contradictions. Alternative planning on the one hand corresponds to alternative, that is, contradictory, but equally valid hypotheses. Only it does not go beyond a certain point. This point, of course, cannot be determined objectively. It is rather the moment in which the inevitably speculative reaches a degree which causes discomfort to the author of the hypothesis, the archaeologist, for instance. It is the same uneasiness that afflicts science in the face of the complete cre-

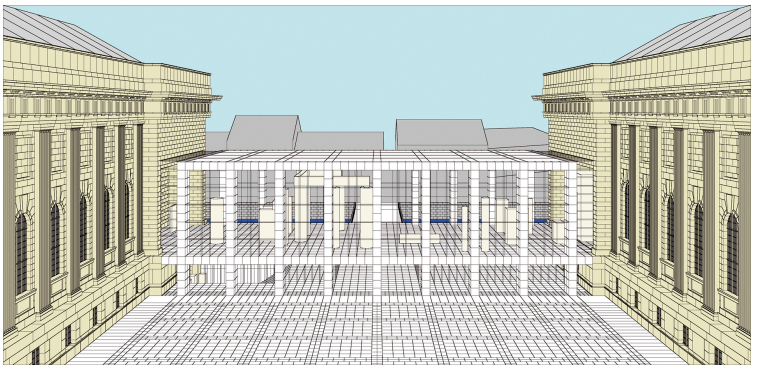

Fig. 19 Entry for the 2001 completion for the conversion of the Pergamon Museum Berlin

Fig. 20 Palatine Palaces in the time of Emperor Maxentius, Rome

ation of real-looking fantasy worlds that is common in the film and games industry, only in consideration of the scientifically acceptable, justifiable part of the representation. Ideally, it is possible to achieve a state of the model that at least does not contradict science (Fig. 21).

However, model building in the design phase differs in one very decisive point from model building that imitates physical reality. Where-

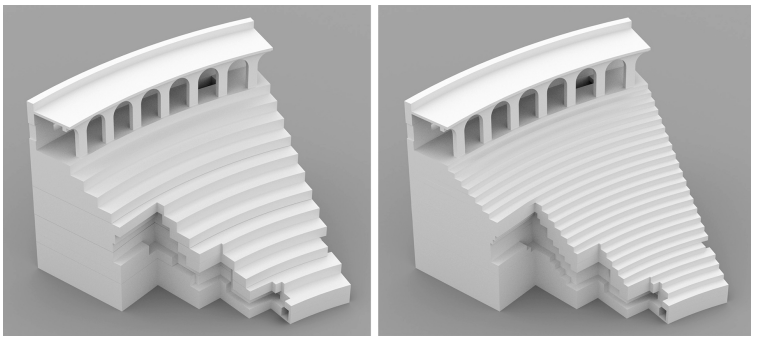

Fig. 21 Simulation of wooden models of a 16th section of the Roman amphitheatre of Dyrrachium, Durrës, Albania

as imitation has an unquestionable reference, namely physical reality, and can not only orient itself to it, but is also measured against it in order to look real, as well as only having to imitate its components, model building in the design phase has no visual reference in physical reality at its disposal. The only references are other models from other design processes. These, however, do not have to match the content at hand, and so it is a matter of weighing whether or not they apply at all. Finally, in any case, in abstract model making there is a need to create forms completely from scratch, representing ideas that have a completely different appearance in physical reality. It is this need to create something entirely new that necessitates the involvement of a design discipline, and in the case of the creation of space-representing forms, this would be architecture (Lengyel and Toulouse, 2013, pp. 327–352).

Now it may seem plausible, and practice shows that this is often the case, to understand the visualization of hypotheses as a technical process. Humanities scholars, unaware of the importance and raison d'être of designing disciplines, may hope that technically skilled model makers, whether analog or virtual, classical model makers or computer experts, are able to translate verbal hypotheses into models. And often what emerges is something that reveals a non-negligible relationship between hypothesis and model, merely that such

models often lack that which, even in architecture, makes the difference between those buildings that merely serve their purpose and those that go beyond it. This issue is perhaps the most difficult in the entire field of visualizing hypotheses as well as in design as a whole. It is as easy to argue that design is a matter of experience as it is difficult to impossible to argue this to someone who has no perceptual sensitivity to design. For this reason, this paper intends to be no more than a proposition. Perhaps the only truly viable argument may be that there is precisely a discipline that has dealt with the design of architecture over millennia that goes beyond the purely utilitarian. It is therefore at least very unlikely that the design level, that is, the quality of the design alone with the same measurable usability of a building, is mere illusion. Perhaps at some point it will be possible to quantify design, but the discipline is still dependent on people of the same mind who recognize the value of high-level design from other disciplines, even if they themselves are not actually equipped to create it.

The design of abstract forms intended to stand for ideas, as formulated in the verbal hypotheses in the humanities, proceeds, like the architectural design process as a whole, through the tentative creation of a variety of alternative forms that are evaluated while still in the process of being created. This procedure is inherent in designing as a whole; it is fundamentally different from any form of reasoning, inductive or deductive, if only because there is no unambiguous or even objectively measurable result, not even a comprehensibly optimal solution. There is basically nothing but the subjective assessment of appropriateness, and the more people involved, the broader the basis of this subjective assessment. As already described in the evaluation of design above, the level of design depends on the qualification, in purely disciplinary terms, of the persons, even if this itself is again not measurable. In concrete terms, all possible forms are examined one after the other to see whether they are suitable for what is to be represented. Thus, it is explicitly not merely considered whether they come into question. The fundamental difference between any form of theoretical science and design lies in the trying out. The forms are apprehended and thoroughly tested in use. Even

for experienced designers, it is the trial that provides insights that did not occur in the theoretical preliminary consideration. A common example of this cognitive process is hand drawing, where the line is evaluated in the process of its creation and then validated or discarded, that is, overdrawn (Fig. 22).

Perhaps the most fundamental component of architecture is the house. The house as a metaphor of meaning is already inexhaustible, but the house as geometry is no less complex. Built, the house does not consist of the one building, but of the multitude of concretizations of the idea of the house. One possible explanatory model is to describe the house as the geometrical framework that facilitates accommodation. But this is only one of many possible ways of explanation. Nevertheless, the verbal term is as common as it is unsuspicious. But only in its verbal form. As soon as it gets to the object level, it becomes difficult to retain its generality. In the visual, the pictogram still succeeds best, especially since it has been used as a metaphor for the starting point of any kind of visual branching and has been given the basically strange addition of being a button. How little building is left in the term home button, however, is another question, and on many digital devices that still have input keys at all, the designated home button does not even carry the symbol of the house anymore, so that its name has developed a life of its own. However, the temporarily visible symbol of the house is, in its simplest form, a symmetrical pentagon with at least two right angles rising above a horizontal baseline. The spatialization of this pictogram is far less common, but works in the same way. Repeated in the third dimension by displacement with a volume added that extends exactly between these two then-parallel pictograms—a process geometrically called extrusion—basically results in a three-dimensional version of this pictogram with an identical interpretation depending on the viewing direction, just like a house. Geometrically, it is then a so-called vertical prism, and the viewing direction is therefore decisive, because the essential features of the house continue to be revealed only in the elevation. From the side, on the other hand, at the contour of the object is a pure rectangle, just a rectangle with a horizontal subdivision, which can be interpreted as a divided rectangle or as

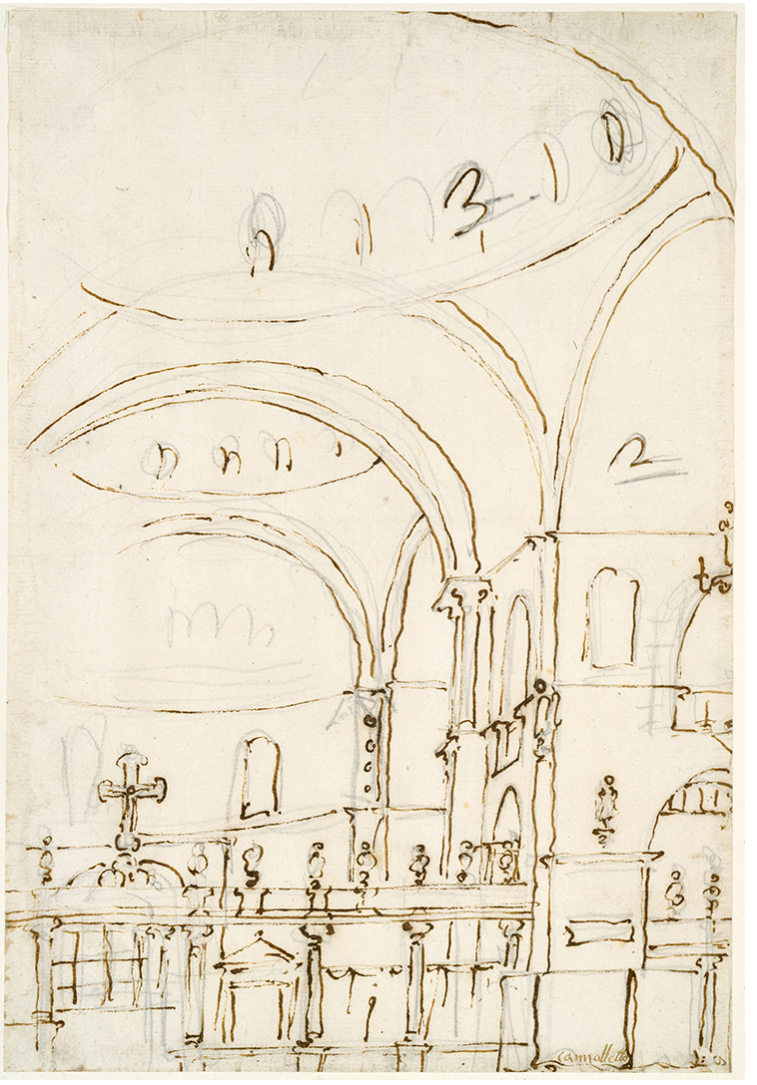

Fig. 22 Interior of the Basilica of San Marco, Showing the Crossing and the Choir, by Giovanni Antonio Canal, about 1763–68

Fig. 23 Three Streets, Hubert Kiecol, 1989, Museum für Moderne Kunst Stiftung Ludwig, Vienna

two rectangles with a common side. Here already it becomes clear that the viewing direction, geometrically speaking the projection, of a three-dimensional model has a considerable influence on the interpretation of the visible, especially, this should be taken in advance, in the case of abstract geometry (Fig. 23).

Just as the house described above is representative of all concrete variants of the house type, most architectural elements can be summarized in the form of types at almost any conceivable hierarchical level (Fig. 24). The lateral appearance of the house as a divided or double rectangle, for example, already specifies the house as a house with a gable roof, while other roof forms such as the hip roof or the pointed roof would create a completely different appearance. The same applies to subordinate elements of the house such as the window or, to remain with the example of the hypotheses from the humanities, to capitals of the classical Greek temple architecture. For even if this type is narrowed down one step further, that is if, as in the example of the temple on the Niyazitepe near Pergamon, the architectural fragments found clearly indicate a Corinthian column order, that is if it is a Corinthian capital, on the one hand much has been said, and presumably a completely clear image comes to the reader's mind, leaving no further questions unanswered, but in fact this component is also of the greatest abstraction, as is the

house described above. For as little unambiguously as the term house describes a concrete house, so little unambiguously does the type Corinthian capital describe its actual appearance. Because there is not the one Corinthian capital; there are very many which are summarized in this type. But the type in itself is not a concrete object; the type does not exist in physical reality, just as a house that resembles the pictogram of the Home Button does not exist. The type is a pure idea; it has no appearance. However, it is possible to communicate the idea of the type visually, but this visual appearance is by no means unambiguous or even objectively right or wrong, but merely a suggestion that functions in the respective context, a suggestion that may point to the correct idea depending on the recipient.

The aim of the design, the invention of a form for the idea of a Corinthian capital for the temple on the Niyazitepe, was to complete the picture of the visualization of the hypothesis of the appearance of a corner of the temple front. The finds, sparse as they are, allow a very extensive reconstruction of almost all parts of the corner, but just not of the capital. Thus, it would be almost possible to reconstruct the corner in such a way that it resembles the physical reality, but the capital is missing completely. However, in order to make the

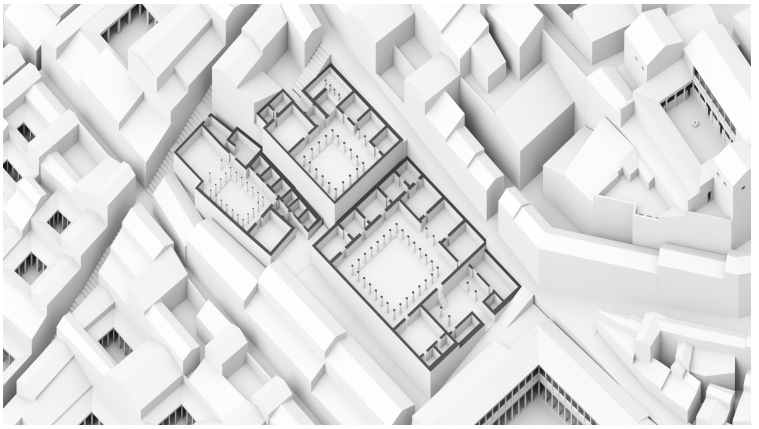

Fig. 24 Vernacular buildings in Pergamon around 200 CE

finds appear in their original function as part of a larger composition, they ought to be arranged in their original context, as the corner of the temple front. Here, however, there remains a significant gap between the column shaft and the column entablature, which is so obvious that the corner cannot develop its original spatial effect in any way. Something must clearly, visibly connect these two components, and according to the rules of classical antique architecture (Binding, pp. 100-104), this can only have been a Corinthian capital (Fig. 25).

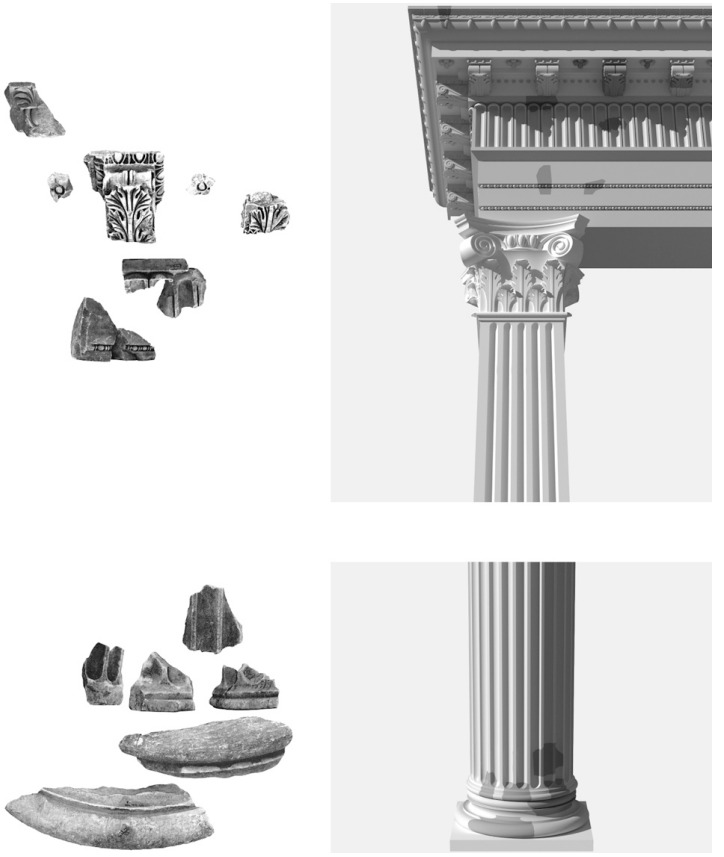

Fig. 25 Temple on the Niyazitepe near Pergamon

A conceivable solution to fill this gap would be to use a Corinthian capital from another building (Fig. 26). This would have plausibly filled the gap at first, but Corinthian capitals are individuals, so such a capital would be a traceable set piece of another building. This would create a significant semantic link to the building of origin of the set piece, for which there is no other justification. The fact that ignorance of the origin avoids the misunderstanding is irrelevant because, first, the ignorance can be cleared up, and second—and this is perhaps the more significant objection—the fact that the capital does not belong to the finding would be obscured for the viewer. Another conceivable solution would be an imitation, that is, a new variant created from the multitude of known Corinthian capitals, which may well seem plausible and could well exist for some time as an unidentified plagiarism in the manner of a forgery. But even if this circumstance is disclosed in an accompanying text, it is initially, that is, in the visualization, concealed, and thus subject to a similar potential for falsification in the perception of the viewer as the approximation of physical reality.

One solution to complete the corner of the temple front, avoiding the problems of concealment mentioned above, is to use a representative that is obviously, immediately, and intuitively recognizable as a type, such as does not occur in physical reality—the abstract. To be able to recognize this object thus created as a type, while at the same time integrating itself into its context, that is, creating for the viewer a plausible environment for the findings, bringing them together, and making the visible appear as a part, as a section of a building, it must be in an ambiguously definable state that can be called uncertain. Uncertain, however, is not meant in the same way as completely without any knowledge, but in the way that the object is not determined, that it resembles many individual Corinthian capitals, but resembles not one of them, and at the same time clearly does not look real, but clearly simplified, so that it is not mistaken for an individual imitation, taken from or imitated by physical reality. It is this delicate balance that requires the competence of designing, the iterative, open-ended, non-calculable process of finding form out of nothing (Fig. 27).

Fig. 26 Acrotere on Trajan's temple in Pergamon

Fig. 27 Temple on the Niyazitepe near Pergamon

The situation is quite similar at the other end of the scale of architecture, the urban quarter. Here, too, findings provide the basis, but here, too, neither copies nor imitations can avoid misunderstandings. Therefore, it is also important here to develop representatives of the type that relate as clearly as possible to time and region and can thus be assigned without giving the impression that they are concrete findings. In the example of Pergamon, the authors have applied this method in different weightings, which result from topographical circumstances such as the slope of the hill or from classical urban planning circumstances such as the proximity to main traffic axes, the city wall, and the city gates, and were defined accordingly by the archaeologists as parameters for certain types, sizes, and arrangements of buildings. The basis, however, for the concrete design of the abstract geometry, which again had to be able both to establish a clear relationship to the architecture of the time and region, and to clearly reveal that these are types, was an excavation on the ridge of the slope, which was analyzed in two different ways in order to obtain a large fund of templates that could be recombined in many ways. The method was to consider separately the two dimensions of geometry and topology, meaning the size of the spaces and their interconnection. In this way, as in reverse engineering, it was possible to recreate a plausible imitation not of any buildings, but of the process of designing them, in order to create the geometric and topological structure of new buildings (Fig. 28).

Fig. 28 Eastern slope of the city mountain of Pergamon

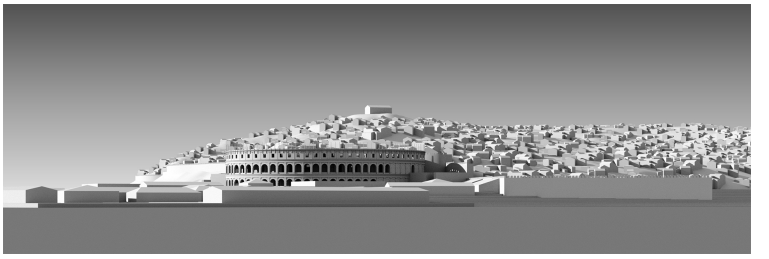

Fig. 29 View from the sea to the Roman amphitheatre of Dyrrachium, Durrës, Albania

The effect that in both cases the abstract geometry seems to lose its abstraction from a great distance and can no longer be distinguished from findings then corresponds to its contribution to the overall representation, because the findings then also no longer develop their own individual appearance and function as part of a larger context, but this then in conjunction with the abstract, uncertain additions. And so the viewing distance as a central variable in photography plays a significant role here as well (Fig. 29).

VIRTUAL PHOTOGRAPHY

The visual rendition of the models, that is the projection of both physical and virtual models, plays such an important role that the authors speak of virtual photography, which should express nothing else than that the entire experience of the discipline of photography cannot be neglected even for the projection of abstract models, that is, that the visual display of virtual models is subject to the same rules and regularities as the photography of physical reality (Fig. 30). Since this paper, as pointed out here and there, is not intended to be a presentation of evidence, the reference to the raison d'être of the discipline of photography ought to suffice here as well, in order to demonstrate plausibly that the absence of the competence of photography in the projection of models generally leads to a decline in the quality of the representations. This is because, like model making, photography is also a design discipline. It, too, has some clearly identifiable rules, but beyond that, it is just as open-ended, incalculable, iterative, and branching as any other formal design discipline.

Fig. 30 Hypothetical ideal church by Würzburg's Prince-Bishop Julius Echter von Mespelbrunn

Before the design in photography, however, there are some points related to human vision that are worth considering in more detail. Since the goal of visualizing hypotheses about architecture is to make them understandable via the image, that is, ultimately to explain them, it is necessary to compensate as much as possible for human vision, which defines visual perception when experiencing architecture in physical reality. Even stereoscopic projection in 3D glasses is not yet capable of actually simulating spatial vision due to its too-small field of view, and if the field of view will in the future presumably encompass the entire range of vision of the eyes, which in the horizontal plane is more than a semicircle, there still remains accommodation, that is, the adjustment of the lens in the eye to the distance of the viewed object (Fig. 31), whereby depth information as part of the interaction with the environment is essentially involved in the construction of the mental image of the natural environment in physical reality, for each individual eye, even without stereoscopy. Nevertheless, our visual experience also includes the interpretation of perspective monoscopic projections, which are then able to compensate for a relevant spatial experience if some basic conditions are met. For this, basic knowledge of descriptive geometry is helpful, as it is also traditionally taught in the discipline of architecture.

Perhaps the most significant property of a perspective projection, for example a photograph, is its unambiguity in terms of spatial classification, namely in terms of orientation and scale. The purpose of such unambiguity is, in a sense, the opposite of optical illusions. While intentional optical illusions such as the illusionistic dome in the Chiesa del Santissimo Nome di Gesù in Rome intentionally invite the viewer to imagine that the space is actually crowned by a dome, here we are concerned with more unintentional illusions that must be avoided. And these relate primarily to the position and size of objects in space. In physical reality, these questions do not arise because the visual impression of space is the integral of a multitude of various visual impressions, created mainly by the movement of the body through space as well as of the head and the eyes while moving (Fig. 32). Additional help with orientation and scaling is provided by details and objects of everyday life, quite profane visual stimuli such as stair

Fig. 31 Plaster cast of the Ludovisi group in front of the hypothetical reconstruction of its original location, the sanctuary of Athena in Pergamon

railings and electrical outlets. How misleading a deviation from the standard can be even in these actually unambiguous indicators can often be experienced in the palace architecture of the Baroque period, where the door handles are at shoulder height. And this is so, although they are only elevated, but nevertheless still in the normal, easily graspable scale. A still picture, on the other hand, is always abrupt; it stands there suddenly without preparation or introduction. All those cognitions, which would be present when proceeding through the space, are missing. The mental model, however, that has been constituted in the imagination while approaching the location, is generally completely consolidated with respect to orientation and scaling. Exactly this has to be compensated in a single image. Some extremely helpful measures for this are easy to implement.

The first aspect, orientation, can be projected in perspective without distortion when the image plane is perpendicular. Then, all perpen-

Fig. 32 Interior of the choir of Cologne Cathedral, 1856 CE

dicular object edges are also depicted perpendicularly in the projection and even further parallel to each other (Fig. 33). Thus, the image simply corresponds to the mental model, no more and no less. So it is not about the parallelism of the walls, but about the mental model inscribing this parallelism into the objects in a spatial experience. The general scale, actually the absolute size of what is perceived, is less clearly to be guaranteed. However, a sufficient measure in most cases is the consistently identical eye level for all perspectives. By perceiving a series of such images, the viewer becomes aware of which object has which size, despite the greatest abstraction of the depicted architecture, since the perspective alignment reveals horizontal spatial edges sometimes as ascending and sometimes as descending lines to the vanishing point as being below or above eye level.

These manageable rules alone, however, do not make for convincing photography. There is much more to it (Shulman, et al., pp. 235–261), as said before, both in photography and in modeling. Achieving a quality here that is not characterized by coincidence or triviality, but reaches a constant level of design, is always an elaborate design process. A lot of experience can increase efficiency, but even with extensive experience, each design question presents its own challenge,

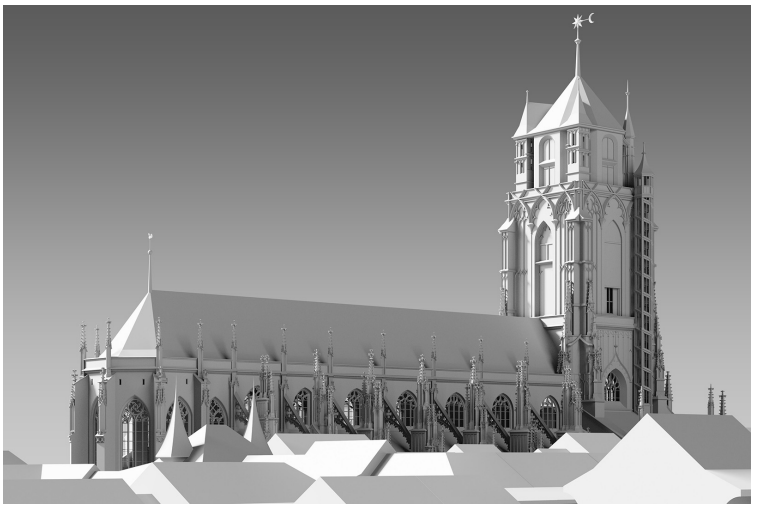

Fig. 33 Bern Minster 1529-1588 CE

which must be met if a high-quality result is to be achieved. Neither can it be achieved by simple recipes, nor can it ever be claimed with certainty that what has been achieved is the absolute final result of the process, the optimum, the perfect solution. Apart from changing circumstances, the human brain is also determined by its internal structure to produce different results as being equivalent under the same preconditions (Kahneman, et al., pp. 399-415), and this particularly applies to design, to which truly objective criteria for evaluation remain unknown. Genuine quality is only unambiguously ascribed by the reception of the future, relevant quality of current creations by the reception in the public and the professional world of the designing disciplines (Fig. 34). Eventually, in the case presented here of a visual language for hypotheses about architecture, it can be measured by its ability to stimulate the imagination of its viewers.

Fig. 34 Abandoned Farm in the Dustbowl, Coldwater District, near Dalhart, Texas, June, by Dorothea Lange, 1938

CASE STUDIES

The method presented here has been developed by the authors in numerous scientific collaborative projects, including the construction phases of the Cologne Cathedral, which were exhibited in the Roman-Germanic Museum in Cologne (Otten, et al., pp. 546–547), cited as a picture quotation among others in books about the city of Cologne, especially in the time of the predecessor buildings of the Cologne Cathedral, presumably because of the particularly pronounced uncertainty (Dietmar and Trier, p. 88). In earlier publications, by contrast, hypotheses were still visualized without including the architectural approach, that is, among other things, by linear extrapolation of the finds (Hauser, pp. 45, 48). Especially in the case of the Cologne Cathedral, which was built on the ground of its predecessor buildings of the early Middle Ages (Ristow, et al.,

pp. 99–100) up to its present Gothic structure (Back, et al., pp. 108–110) with special attention to its execution in terms of the materiality of its building blocks (Kölner Dom and Plehwe-Leisen, et al., p. 79), has been extensively studied, and, on the one hand, according to the cathedral building administration, is a permanent construction site and, at the same time, the literature speaks of its completion (Schumacher, p. 110), even referring to the entire twentieth century as the century of its completion (Borger, et al., pp. 9–16), presumably because with the completion of the west façade, the planning from the 13th century CE had been implemented (Steinmann, pp. 257–260); the architectural view was decisive for several shifts in interpretation, such as the supposed crossing towers on the Hildebold Cathedral or the extension of the 6th-7th-century church (Fig. 35), which is now more probable compared to the new construction (Schock-Werner, et al., pp. 69-74). Interpreting the existing archaeological foundations in a new way alone as an architect resulted in slight but nonetheless significant adaptations, especially to the appearance of the early predecessors of the Cologne Cathedral. The most striking feature is probably the omission of the crossing towers of the Hildebold Cathedral (Fig. 36). But also the extension compared to the new construction of the 7th-8th-century CE church or the stepped floor within the same church was the result of the architectural view (Fig. 37). An example of a polychrome visualization here of art historical hypotheses is the interior of the choir of Cologne Cathedral shortly before the destruction of the partition wall to the later transept. Here it was possible, due to the detailed documentation and the to a large extent preserved interior equipment, to supplement the visualizations with an equally reliable statement on polychromy with the same scientific standards (Klösges and Metternich, p. 150–154). Due to the considerably higher level of documentation, fewer findings were to be expected from the visualization, but still, this first compilation of all the documents, especially the ink drawings of the organ gallery and the choir stalls, led to the first consistent overall model, which resulted in some of the drawings having to be corrected in terms of their measurements (Fig. 32). The work on the Cologne Cathedral has also been published in es-

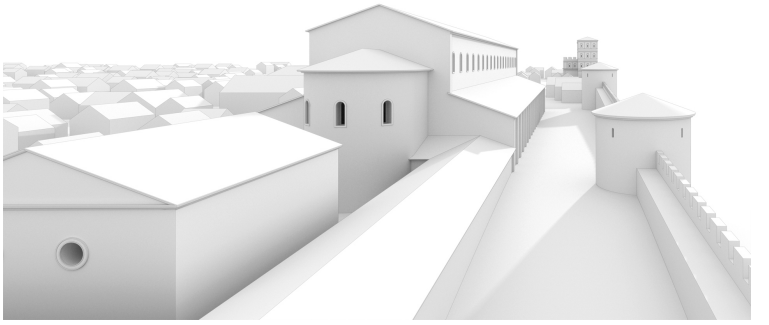

Fig. 35 Cologne Catheral's predecessor of the 7th and 8th centuries CE

Fig. 36 The Hildebold Cathedral, Cologne Catheral's last predecessor

says dealing with theoretical issues relevant to visual language, such as authenticity (Bernhardt, et al., p. 82).

A special case is the construction phase of the Bern Cathedral, because it deals with the visualization of a building project that was never realized due to a change in the building intention (Fig. 38).

Fig. 37 Cologne Catheral's predecessor of the 7th and 8th centuries CE

In the new scientific compendium of the first century of the Bern Cathedral, there are therefore 48 visualizations by the authors in seven contributions by four different contributors (Nicolai and Schweizer, pp. 86, 89, 92, 98, 100,101, 103, 105, 108, 109, 113, 120, 121, 130, 131, 137, 140, 141, 144, 145, 219–228, 314, 329, 339, 341, 348, 433, 437, 439, 441, 564–566, 570, 572). The impact of the visualization here was varied. On the one hand, the construction method in computer-aided design revealed unexpected irregularities. On the west façade, for example, the parapet of the north aisle is several feet higher than the parapet of the south aisle, which when simply looking at the building seems unnoticeable (Fig. 39). The aspiration to spatially define the predecessor church for the first time led to a whole series of different solutions, until eventually the massive foundations were defined as the tower foundations as the final solution, and the predecessor church was thus assigned a stately bell tower (Fig. 40).

Equally polychrome, due, among other things, to the epoch at the beginning of the 17th century CE, it was possible to visualize an ideal church, which is a hypothesis in two ways. The first hypothesis is that the prince-bishop in charge, Julius Echter of Mespelbrunn, developed the ideal of a parish church in his imagination, since his sev-

Fig. 38 Hypothetical original planning of Bern Minster with western gallery

eral hundred realized examples are strikingly similar. The second hypothesis concerns its four main components: nave, choir, tower, and sacristy (Fig. 41). And because its visualization is not so much abstraction as idealization of existing components of different realized churches, it allowed it to be polychrome (Dombrowski, et al., pp. 116, 118, 127–129). Since the ideal church itself is a mere hypothesis, there was no concrete impact on the findings of the realized churches in this project (Fig. 42). What became most obvious, however, were the irregularities in their execution. Even though no reasons could be found for this so far, it is clear from many individual cases how much the ideas deviated from their realization. This is particularly obvious

Fig. 39 Bern Minster around 1505 CE

in the case of the beamed ceiling, which was selected as most typical (Fig. 43). In its idealized form, it can be described in a few words, while its realization shows striking and, above all, incomprehensible irregularities, which could provide impetus for research into the execution practices of the time.

The ancient royal city of Naga in today's Sudan, on the other hand, which was located at the intersection between classical antiquity, ancient Egypt, and the southern African continent, can only be traced in the form of foundation tracks, except for a few towering temples (Fig. 44). Nevertheless, a visualization of the city was possible on the basis of the building structures and slight hints of the construc-

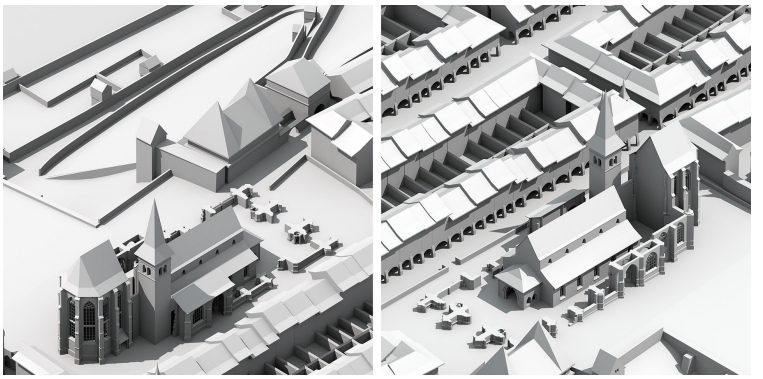

Fig. 40 Bern Minster and its predecessor from 1438 to 1440

tion methods alone, especially due to the great distance of the viewer's standpoint, which led to panorama-like perspectives, extremely horizontal formats in an aspect ratio of one to fourteen (Fig. 45), which could be folded out in the exhibition catalog (Kroeper, et al., pp. 163–175). In the exhibition, the resolution of the images allowed it to act both as a background for the exhibits and to convey very high-resolution details (Fig. 46, a section of Fig. 3). It was the project directors themselves who were surprised at the presence of the secular buildings, which they themselves had defined, despite decades of involvement with the project. A separate set of plans was prepared as a legend for the *vedute* in order to make the numbering of the individual buildings used in the floor plans visible in the elevations as well. Only in this way could the ground plan and the views be comprehensibly brought together; the city appeared too unexpectedly dense after the translation of the verbal hypotheses into their visual counterpart.

Many projects are located in classical antiquity: smaller ones such as the House of the Two Skeletons in Morgantina (Trümper, pp. 405-406), but mainly larger excavation projects like the Palatine in Rome (Fig. 47), which was first presented in a major exhibition at the Pergamon Museum Berlin (Märtin, et al., pp. 12–23), but later also found its way into scientific publications as pure illustrations,

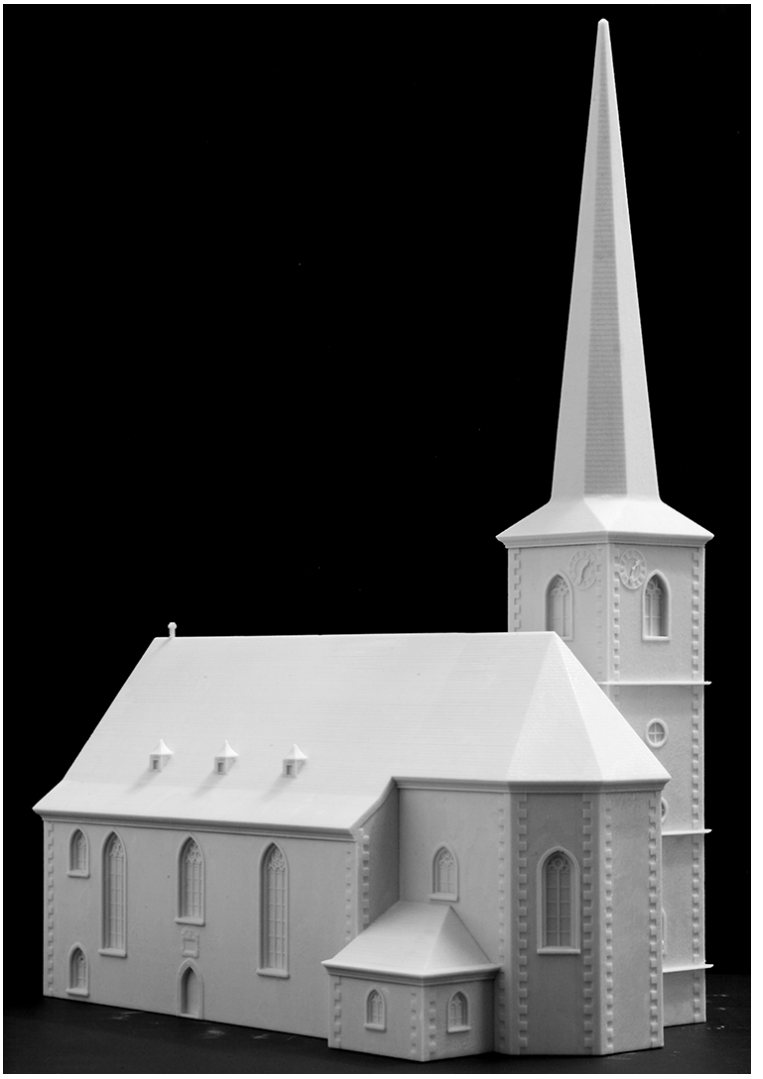

Fig. 41 3D print of a hypothetical ideal church by Julius Echter

in this case even with a supplementary commentary on the visualizations' appearance (Kelly and Hug, vol. 1, pp. 223, 230; vol. 2,

Fig. 42 Hypothetical ideal ensemble of church, rectory, and school by Julius Echter

Fig. 43 West gallery of the hypothetical ideal church by Julius Echter

pp. 33–34, 56–57). Here it was again the photographic view as the primary means of perceiving architecture that brought about a new aspect of the imperial palaces (Fig. 48). Whereas the representations before were mainly limited to the bird's-eye view and the direct opposite of the Imperial Lodge, the search from an architectural point

Fig. 44 Cityscape of the royal city of Naga seen from the inside

Fig. 45 Cityscape of the royal city of Naga seen from the caravan route coming from the north

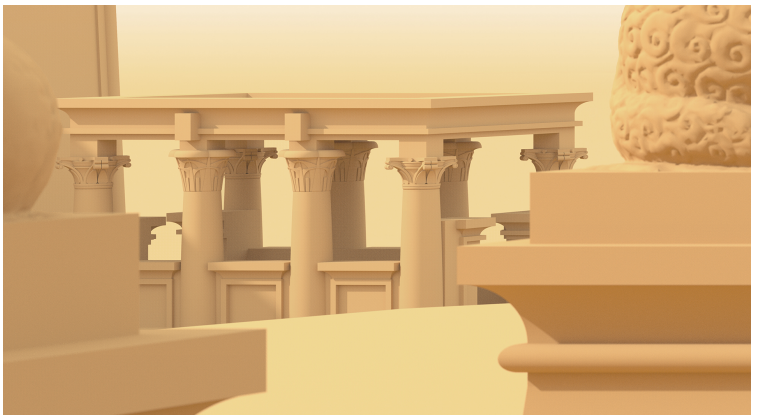

Fig. 46 Section of the view from the temple of Amun in the royal city of Naga

of view led to what later became the most significant perspective from the auditorium towards the Imperial Palaces, namely diagonally across the circus from the covered upper tiers (Fig. 49). This viewpoint unites the characteristic form of the circus with the pres-

Fig. 47 Domus Severiana with water basin on the roof terrace of the Domus Severiana in the time of Emperor Hadrian

ence of the imperial palace as a demonstration of power to the people. How important and expressive the Imperial Palaces building site must have appeared to the people becomes particularly clear from this perspective.

Finally, Pergamon, starting from the first monographic exhibition in 2011 at the Pergamon Museum Berlin (Grüßinger, et al., pp. 68, 69, 73, 77–79, 84–86, 146, 165, 252–253, 261–263, 266,273, 275, 307), whose film projection, on the occasion of an exhibition in 2017 at the Collection of Classical Antiquities of the University of Leipzig (Lang, et al., outer and inner flaps, pp. 9, 21, 23, 25, 27, 29, 33, 48–54), was supplemented by a speaker's commentary, accounts for the most publications as ongoing research of a major ancient metropolis, including many by the authors who benefit from the large body of existing and potential illustrations (Fig. 50). As a result, many visualizations are produced in this cooperation, which has been ongoing continuously since 2009, due to specific needs, for example on the occasion of an exhibition at the Museum of Antiquities of the University of Freiburg on ancient sculpture (Petersen, Lars, et al., pp. 22, 25, 29, 32). The collection catalog of the Pergamon Museum Berlin

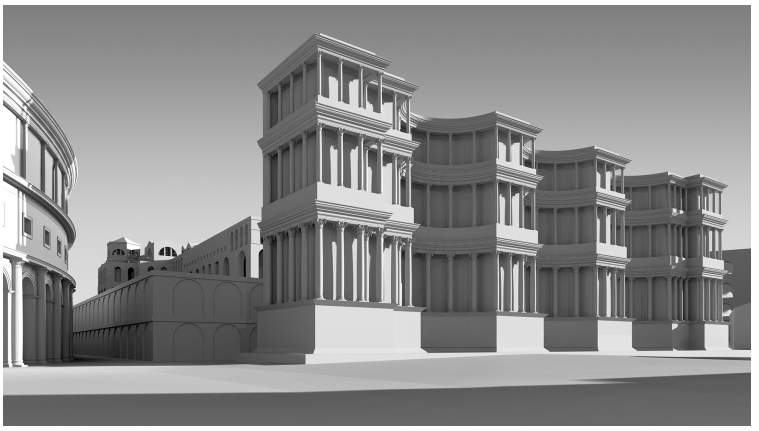

Fig. 48 Septizonium fountain after a drawing by Maerten Jacobsz van Heemskerck in the time of Emperor Maxentius

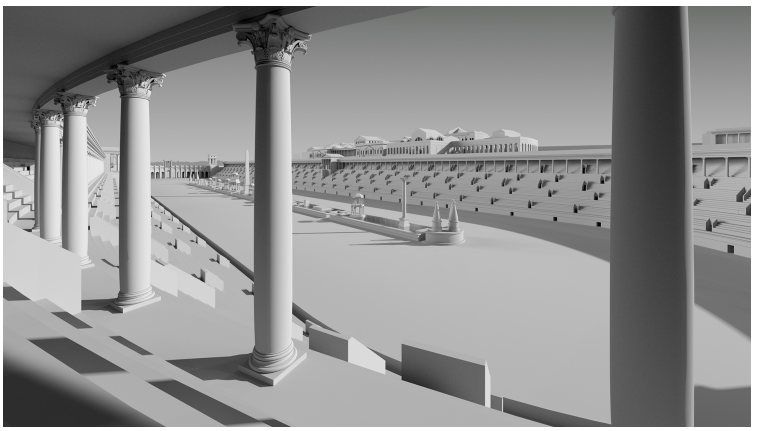

Fig. 49 The palaces of the Palatine seen from the Circus Maximus in the time of Emperor Septimius Severus

(Staatliche Museen zu Berlin), which usually lists exhibits from antiquity, shows its abstract visualization next to a photo of the Great Altar of Pergamon. One of the insights gained from the first com-

plete virtual model of the metropolis resulted from the search for a viewpoint, which could certainly already be taken in antiquity, from which an overview of the most complete possible city skyline could be obtained (Fig. 51). Despite over a hundred years of research, this question had only arisen with the explicit inclusion of an architectural view specialized in visualization. Unlike in other cases, where the objective was to examine whether or not certain sculptures had been visible from certain points in the city, here the focus is purely on visual appreciation. The result is a perspective that does not provide any unexpected insights or answer any unresolved questions. To the contrary, it does nothing more than reveal an urban quality, a subtle variable in the urban planning of Pergamon, the answer to the question of the reason for the large terrace of the Altar of Zeus, not unambiguous or undisputed, but impressive nonetheless. From the point of view of archaeology, it is merely an impulse to investigate in this matter; from the point of view of architecture, it is a clear indication of a comprehensible architectural design intention aimed at generosity and impressiveness (Fig. 52), just as one would like to find in contemporary architecture today.

Numerous other collaborative research projects examine various other aspects of visualization, including the Stabian Baths and Republican Baths in Pompeii, several buildings in the Roman city of Baalbek in present-day Lebanon, the Sasanian summer residence Ktesiphon in present-day Iraq, the Sasanian palace complex Tacht-e Suleiman in present-day Iran, a three-dimensional version of the facade of the square around the Dome of the Rock in Jerusalem based on modern measurements and a historical drawing in ink, a medieval square in Lüneburg in Germany, and several studies on the interaction of colours in interiors featuring examples from antiquity to classical modernism.

CONCLUSION

Frequent enquiries for the inclusion of the visualizations in the publications of other people show us that there is indeed a demand for this form of scientifically based and graphically ap-

Fig. 50 The city mountain of the metropolis of Pergamon around 300 CE

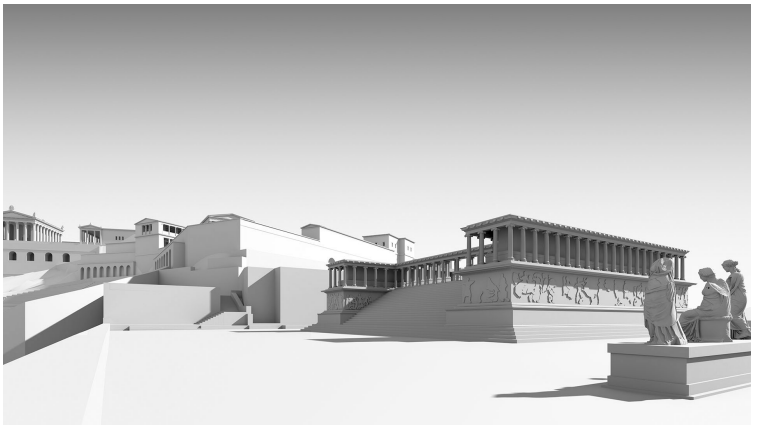

Fig. 51 The skyline of the metropolis of Pergamon as seen from the southwest corner of the Terrace of the Great Altar

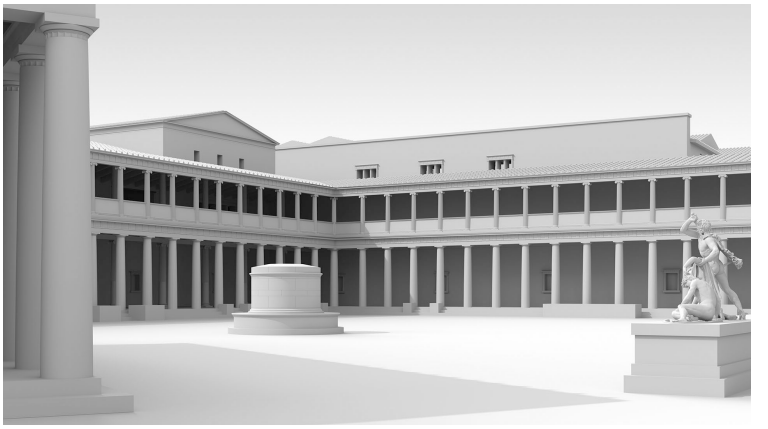

Fig. 52 The sculptures Gruppo Ludovisi and Dying Gaul, preserved only as marble copies, today in Rome, in their original setting in the sanctuary of Athena in Pergamon

pealing visualization. It is not only the sciences themselves that benefit from the vicinity of the visualizations to science, it is also architecture and, via these means of access, in the end also the public that can examine hypothetical spatial structures in a way that would not have been possible even in their originally realized state, namely as a pure idea. Abstraction is not a loss; on the contrary, it is on focusing. To the same extent that materiality and polychromy are left out of the majority of antique projects, expression grows in terms of geometry, form, structure, and spatial composition. It is not without reason that the virtual model of Pergamon, which has been created over the last fifteen years in close collaboration with the excavation in Bargama and the Istanbul department of the German Archaeological Institute, is to be exhibited in the Altar Hall of the Pergamon Museum Berlin after its current renovation as two successors to the historical models and for the first time as tactile models, milled from Corian, as permanent installations. Architectural motifs in the absence of their historical context actually become exemplary models for contemporary designs as well. Timeless concepts ranging from spatial proportion and tectonics to geometrically sophisticated solutions for the transition from sloping to flat surfaces, for example, or lighting

design in general, become all the clearer the more the viewer's attention is drawn to and focused on them. The method of visualizing architectural hypotheses in the humanities presented here is in this way equally an access to the immaterial history of architecture, to the history of ideas of design, the intellectual achievement beyond the realization of the building, in a certain way the access to the idea of architecture itself.

WORKS CITED

Arnheim, Rudolf. *Anschauliches Denken: Zur Einheit von Bild und Begriff*. 6th ed., DuMont, 1988.

Back, Ulrich, and Thomas Höltken. *Die Baugeschichte des Kölner Domes nach Archäologischen Quellen: Befunde und Funde aus der gotischen Bauzeit*. Studien zum Kölner Dom 10. Verlag Kölner Dom, 2008.

Bernhardt, Christoph, et al., editors. *Gebaute Geschichte: Historische Authentizität im Stadtraum*. Wallstein, 2017.

Binding, Günther. *Architektonische Formenlehre*. 4th, revised and suppl. ed., Primus, 1999.

Borger, Hugo, et al., editors. *Der Kölner Dom im Jahrhundert seiner Vollendung*. Historische Museen der Stadt Köln, 1980.

Dietmar, Carl, and Marcus Trier. *Colonia – Stadt der Franken: Köln vom 5. bis 10. Jahrhundert*. 2nd ed., DuMont, 2011.

Dombrowski, Damian, et al., editors. *Julius Echter, Patron der Künste: Konturen eines Fürsten und Bischofs der Renaissance*. Deutscher Kunstverlag, 2017.

Glaser, Manuela, et al. "Designing computer-based learning contents: influence of digital zoom on attention". *Educational Technology Research and Development*, vol. 65, pp. 1135–1151 (2017). https://doi.org/10.1007/s11423-016-9495-9

Glaser, Manuela, et al. "How Do We Deal with Uncertain Information? Effects of Verbal and Visual Expressions of Uncertainty on Learning." Educational Psychology Review, vol. 34, no. 2, June 2022, pp. 1097–131. https://doi.org/10.1007/s10648-022-09659-4.

Grüßinger, Ralf, et al., editors. *Pergamon. Panorama der antiken Metropole. Begleitbuch zur Ausstellung* [on the occasion of the exhibition "Pergamon – Panorama der Antiken Metropole" in the Pergamon Museum on the Berlin Museum Island, 30 September 2011 to 30 September 2012]. Imhof, 2011.

Hauser, Georg. *Schichten und Geschichte unter dem Dom: Die Kölner Domgrabung*. Verlag Kölner Dom, 2003.

Hirschberg, Urs, et al., editors. *Atlas of Digital Architecture: Terminology, Concepts, Methods, Tools, Examples, Phenomena*. Birkhauser, 2020.

Kahneman, Daniel, et al. *Noise: Was unsere Entscheidungen verzerrt – und wie wir sie verbessern können*. 1st ed., Pantheon, 2023.

Kelly, Benjamin, and Angela Hug, editors. _The Roman Emperor and His Court c. 30 BC – c. AD 300. Volume I: Historical Essays__. Cambridge UP, 2022.

Kelly, Benjamin, and Angela Hug, editors. *The Roman Emperor and His Court c. 30 BC – c. AD 300. Volume II: Source Book*. Cambridge UP, 2022.

Klösges, Stefan, and Eberhard Metternich, editors. *In Aeternum Cantabo: Zeugnisse aus 1300 Jahren Kölnischer DomMusikGeschichte* [exhibition on the occasion of the 150th anniversary of the Cologne Cathedral Choir From 1 November 2013 to 7 January 2014 in the Archbishop's Diocesan and Cathedral Library Cologne]. Kölner Dommusik, 2013.

Plehwe-Leisen, Esther von, et al. *Steine für den Kölner Dom*. Verlag Kölner Dom, 2004.

Kroeper, Karla, et al., editors. *Königsstadt Naga: Grabungen in der Wüste des Sudan: Naga - Royal City* [on the occasion of the exhibition "Royal City of Naga – Excavations in the Desert of Sudan", Munich, Staatliches Museum Ägyptischer Kunst, 15 April to 31 July 2011, Berlin, Kunstforum der Berliner Volksbank, 31 August – 18 December 2011, an exhibition of the Naga Project of the Egyptian Museum and Papyrus Collection, Staatliche Museen zu Berlin - Stiftung Preußischer Kulturbesitz]. Staatliches Museum Ägyptischer Kunst, 2011.

Lang, Jörn, et al., editors. *Pergamon wiederbelebt! Die antike Residenzstadt in 3D* [exhibition of the Museum of Antiquities at Leipzig University in cooperation with the German Archaeological Institute (DAI), Istanbul Department and the Chair of Visualisation at the Brandenburg Univer-

sity of Technology (BTU) Cottbus-Senftenberg, April to July 2018]. Antikenmuseum der Universität Leipzig, 2018.

Lengyel, Dominik, and Catherine Toulouse. "Die Bauphasen des Kölner Domes und seiner Vorgängerbauten. Gestaltung zwischen Architektur und Diagrammatik." *Diagrammatik der Architektur*, edited by Dietrich Boschung and Julian Jachmann, Wilhelm Fink, 2013.

Locher, Hubert, et al., editors. *Architecture transformed: Das digitale Bild in der Architektur 1980–2020*. arthistoricum.net, 2023.

Märtin, Ralf-Peter, et al. *Jenseits des Horizonts: Raum und Wissen in den Kulturen der Alten Welt*. Theiss, 2012.

Nicolai, Bernd, and Jürg Schweizer. *Das Berner Münster: Das erste Jahrhundert: Von der Grundsteinlegung bis zur Chorvollendung und Reformation (1421–1517/1528)*. 1st ed., Schnell & Steiner, 2019.

Otten, Thomas, et al., editors. *Fundgeschichten – Archäologie in Nordrhein-Westfalen* [exhibition Cologne, Roman-Germanic Museum of the City of Cologne, 19 March to 14 November 2010; exhibition Herne, LWL Museum of Archaeology - Westphalian State Museum, 16 April 2011 to 20 November 2011]. Römisch-Germanisches Museum der Stadt Köln, 2010.

Peirce, Charles S. *Semiotische Schriften, vol. 1: 1865 – 1903*. 1st ed., Suhrkamp, 2011.

Petersen, Lars, et al., editors. *Skulpturen in Pergamon: Gymnasion, Heiligtum, Palast* [catalogue for the exhibition at the Archeological Collection of the University of Freiburg 6 May 2011 to 31 July 2011 in cooperation with SMB Staatliche Museen zu Berlin]. Archäologische Sammlung der Universität Freiburg, 2011.

Reinhardt, Ad. *Schriften und Gespräche*. 2nd, impr. ed., Schreiber, 1998.

Ristow, Sebastian. *Die Frühen Kirchen unter dem Kölner Dom: Befunde und Funde vom 4. Jahrhundert bis zur Bauzeit des Alten Domes*. Studien zum Kölner Dom 9. Verlag Kölner Dom, 2002.

Schock-Werner, Barbara, et al., *Die Bauphasen des Kölner Domes und seiner Vorgängerbauten: Cologne Cathedral and preceding buildings*. 1st ed., Verlag Kölner Dom, 2011.

Schumacher, Thomas. *Großbaustelle Kölner Dom: Technik des 19. Jahrhunderts bei der Vollendung einer gotischen Kathedrale*. Verlag Kölner Dom, 2004.

Shulman, Julius, et al. *Architektur und Fotografie*. Taschen, 1998.

Schwarzmaier, Agnes, et al. *Die Antikensammlung: Altes Museum, Neues Museum, Pergamonmuseum*. 4th, fully revised and expanded ed., Staatliche Museen zu Berlin, 2012.

Steinmann, Marc. *Die Westfassade des Kölner Domes: der mittelalterliche Fassadenplan F*. Verlag Kölner Dom, 2003.

Trümper, Monika. *The House of the Two Skeletons at Morgantina*. Harrassowitz Verlag, 2023.

IMAGE CREDITS

1 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Cathedral administration and master builder Barbara Schock-Werner

2 Photo: Dominik Lengyel, 2011

3 Photo: Dominik Lengyel, Visualisation: Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with The Naga Project, Egyptian Museum Berlin, Dietrich Wildung

4 Photo: Dominik Lengyel, 2019

5 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with The T-Cell project, Chair of Internal Combustion Engines and Aircraft Propulsion

6 The Metropolitan Museum of Art, New York, H. O. Havemeyer Collection, Bequest of Mrs. H. O. Havemeyer, 1929, www.metmuseum.org

7 The Metropolitan Museum of Art, New York, Robert Lehman Collection, 1975, www.metmuseum.org

8 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Cathedral administration and master builder Barbara Schock-Werner

9 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Cathedral administration and master builder Barbara Schock-Werner

10 Photo: Dominik Lengyel, 1995

11 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Cathedral administration and master builder Barbara Schock-Werner

12 Photo: Dominik Lengyel, 2021

13 The Trustees of the British Museum, CC BY-NC-SA 4.0 Deed

14 The Metropolitan Museum of Art, New York, Bequest of Maurice B. Sendak, 2012, www.metmuseum.org

15 Photo: Dominik Lengyel, 2006

16 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with Felix Arnold, German Archaeological Institute DAI, Department Madrid

17 Chair of Architecture and Visualisation, Dominik Lengyel and Catherine Toulouse, in collaboration with Monika Trümper, archaeologist, Freie University Berlin

18 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with Ulrike Wulf-Rheidt, German Archaeological Institute DAI, Architecture Department Berlin

19 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, commissioned by Oswald Matthias Ungers, Cologne

20 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with Ulrike Wulf-Rheidt, German Archaeological Institute DAI, Architecture Department Berlin

21 Dominik Lengyel and Catherine Toulouse, in collaboration with Henner von Hesberg, archaeologist

22 The Metropolitan Museum of Art, New York, Robert Lehman Collection, 1975, www.metmuseum.org

23 Photo: Dominik Lengyel, 2016

24 Chair of Architecture and Visualisation, Dominik Lengyel and Catherine Toulouse, in collaboration with the Excellence cluster TOPOI and the

German Archaeological Institute DAI, Ulrike Wulf-Rheidt, Architecture Department Berlin, Felix Pirson, Department Istanbul

25 Seminar work at the Chair of Architecture and Visualisation, Dominik Lengyel and Catherine Toulouse, in collaboration with Klaus Rheidt, architect and building historian

26 Chair of Architecture and Visualisation, Dominik Lengyel and Catherine Toulouse, in collaboration with the Excellence cluster TOPOI and the German Archaeological Institute DAI, Ulrike Wulf-Rheidt, Architecture Department Berlin, Felix Pirson, Department Istanbul

27 Seminar work at the Chair of Architecture and Visualisation, Dominik Lengyel and Catherine Toulouse, in collaboration with Klaus Rheidt, architect and building historian

28 Chair of Architecture and Visualisation, Dominik Lengyel and Catherine Toulouse, in collaboration with the Excellence cluster TOPOI and the German Archaeological Institute DAI, Department Istanbul, Felix Pirson

29 Dominik Lengyel and Catherine Toulouse, in collaboration with Henner von Hesberg, archaeologist

30 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the former master builder of Cologne Cathedral Barbara Schock-Werner

31 Photo: Dominik Lengyel. Visualisation Chair of Architecture and Visualisation, Dominik Lengyel and Catherine Toulouse, in collaboration with the Excellence cluster TOPOI, the Sculpture Network Berlin and the Plaster Collection Berlin-Charlottenburg

32 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Cathedral administration, art historian and head of the archive Klaus Hardering

33 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Minster Foundation and the University of Bern

34 The Metropolitan Museum of Art, New York, Gift of Phyllis D. Massar, 1972, www.metmuseum.org

35 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Cathedral administration and master builder Barbara Schock-Werner

36 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Cathedral administration and master builder Barbara Schock-Werner

37 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Cathedral administration and master builder Barbara Schock-Werner

38 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Minster Foundation and the University of Bern

39 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Minster Foundation and the University of Bern

40 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the Minster Foundation and the University of Bern

41 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the former master builder of Cologne Cathedral Barbara Schock-Werner

42 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the former master builder of Cologne Cathedral Barbara Schock-Werner

43 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with the former master builder of Cologne Cathedral Barbara Schock-Werner

44 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with The Naga Project, Egyptian Museum Berlin, Dietrich Wildung

45 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with The Naga Project, Egyptian Museum Berlin, Dietrich Wildung

46 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with The Naga Project, Egyptian Museum Berlin, Dietrich Wildung

47 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with Ulrike Wulf-Rheidt, German Archaeological Institute DAI, Architecture Department Berlin

48 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with Ulrike Wulf-Rheidt, German Archaeological Institute DAI, Architecture Department Berlin

49 Lengyel Toulouse Architects Berlin, www.lengyeltoulouse.com, in collaboration with Ulrike Wulf-Rheidt, German Archaeological Institute DAI, Architecture Department Berlin

50 Chair of Architecture and Visualisation, Dominik Lengyel and Catherine Toulouse, in collaboration with the Excellence cluster TOPOI and the German Archaeological Institute DAI, Department Istanbul, Felix Pirson

51 Chair of Architecture and Visualisation, Dominik Lengyel and Catherine Toulouse, in collaboration with the Excellence cluster TOPOI and the German Archaeological Institute DAI, Department Istanbul, Felix Pirson

52 Chair of Architecture and Visualisation, Dominik Lengyel and Catherine Toulouse, in collaboration with the Excellence cluster TOPOI and the German Archaeological Institute DAI, Department Istanbul, Felix Pirson