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(RECOMMENDED CITATION)

ABDUCTIVE IMAGE FORMATION

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ABSTRACT. Our study, according to its title, will consist of four parts. Initially, we want to elucidate the concept of abduction and the characteristics of abductive reasoning. Then we will turn our attention to visual abduction, proceeding from its logical and psychological discussion in the literature. Finally, we will deal with the question whether building design proceeds abductively. If we will assume that it does, then we will argue for this point. Our argument will be based on a specific example, supplied by the design of an archaeological museum by Gál Gabriella. By way of a conclusion, we will present our logical and philosophical interpretations.

Keywords: *abduction, visual abduction, visual coherence, abductive image formation in architecture*

The concept of abduction

The concept of abduction was introduced by the American pragmatist philosopher and logician C. S. Peirce. Although the concept looks back at a history of more than one hundred years, it has not enjoyed too much popularity, especially not in Europe, where its initial scope was limited almost exclusively to the analysis of scientific explanations.

The concept of abduction was put in a new light most notably by the research on artificial intelligence and soft computing, emerging in the 1980s, in which it emphatically proved its usefulness. This is the way in which fields of inquiry like the philosophy of science, medical diagnosis, historical explanation, criminal investigation etc. have come into contact with the concept of abduction. So much so that Lorenzo Magnani used "abductive cognition" as a title for his book published in 2009[3], which also signals the broadening interpretation of the

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[3] Magnani, Lorenzo (2009) *Abductive Cognition. The Epistemological and Eco-Cognitive Dimensions of Hypothetical Reasoning*, Springer Verlag, Berlin, Heidelberg.

concept of abduction. In addition to the area of scientific explanation, abduction has begun to appear in the most varied roles, from the study of sensation and perception to nonverbal creative solutions. Magnani summarizes these developments as follows: "Abduction is a popular term in many fields of AI, such as diagnosis, planning, natural language processing, motivation analysis, logic programming, and probability theory. Moreover, abduction is important in the interplay between AI and philosophy, cognitive science, historical, temporal, and narrative reasoning, decision-making, legal reasoning, and emotional cognition."[4]

But let us begin at the beginning. What did Peirce mean by the concept of abduction? According to Peirce, abduction is a distinct form of reasoning, which differs both from deduction and from induction as known so far. Its distinctive quality is revealed by the following quote, which has become so well-known that it even appears as a motto in the literature.

> „*The surprising fact, C, is observed.*
> *But if A were true, C would be a matter of course.*
> *Hence, there is reason to suspect that A is true.*" [CP, 5.189][5]

The structure of this reasoning may be represented formally as follows:

$$\begin{array}{l} C \\ \underline{A \rightarrow C} \\ A \end{array}$$

In this representation, A and C stand for statements, and $\rightarrow$ is the general symbol of material implication. However, on the basis of the aforementioned observations, it would have to acquire a different interpretation. In the field of informal logic, this form of reasoning is invalid, because the truth of the conclusion establishes the truth of the antecedent. In informal logic, this fallacy is called *fallacy of affirming the consequent*, and it can be avoided by establishing the truth of the consequent on the truth of the antecedent:

$$\begin{array}{l} A \\ \underline{A \rightarrow C} \\ C \end{array}$$ [6]

[4] *Ibid*. p. 5.

[5] Peirce, C. S: C*ollected Papers of Charles Sanders Peirce*. Volumes 1–6 edited by C. Hartshorne, P. Weiss. Cambridge, Harvard University Press. 1931–1935; and volumes 7–8 edited by A.W. Burks. Cambridge, Harvard University Press. 1958.

[6] Gál László (2007) *Hagyományos logika*. Egyetemi Műhely Kiadó, Bolyai Társaság, Kolozsvár, p. 100-103.

This form of reasoning is valid within deductive logic, and it has such a prominent role that it has a name: *modus ponens*. Furthermore, we can notice that the *modus ponens* is linear and reasons in a forward direction (viz., it is deductive, because the conclusion follows the premises). In contrast, within abductive reasoning the premises follow the conclusion, because of which the argument is retroductive. As a result of abduction we arrive at hypotheses (formulation of hypotheses) among which we have to choose in order to find an explanation.

The basic features of Peircean abduction can be summarized in the following keywords:

- *promising hypothesis*: essentially, the definitive characteristic of abduction consists in the formulation of hypotheses on the basis of an observation;
- *explanatory*: the hypothesis is explanatory if it takes into account the facts, because the unexpected fact has to be based on other facts or on our former knowledge in order for us to find an explanation for it;
- *testable*: it is in accord with the testability of the hypotheses, or, in other words, it can be repeated;
- *economic*: the hypotheses have to be *countable*, and we have to be able to *choose* among them the best one *on the basis of clearly established criteria* (the best explanation). Here, a subjective factor also plays its role, associating the abductive reasoning with the reasoner, the agent of abduction, or the abductor.

The concept of intuitive abduction

In order to clarify the above discussion, we will cite here one of the examples of A. Aliseda, who uses it repeatedly in her book on abductive reasoning: „Common Sense: Explaining observations with simple facts. All you know is that the lawn gets wet either when it rains, or when the sprinklers are on. You wake up in the morning and notice that the lawn is wet. Therefore you hypothesize that it rained during the night or that the sprinklers had been on."[7]

We will turn here, again, to the formal reconstruction of reasoning, due to its certified clear and unequivocal character.

The lawn is wet (observation). C
The lawn gets wet either when it rains or when the sprinklers are on. $\underline{(A \vee B) \rightarrow C}$
It has rained, or the sprinklers had been on. $A \vee B$

[7] Aliseda, A. (2006) *Abductive Reasoning. Logical Investigations into Discovery and Explanation*, Springer, Dordrecht, The Netherlands. p. 29.

Proceeding from the observation of the wetness of the lawn, you reason back to what you already know and are convinced of, i.e. that it has rained, or that the sprinklers had been on. In other words, you have advanced an *abductive explanation* on the basis of what you know and are convinced of (background knowledge).

As already mentioned, this form of reasoning is not valid from a strictly logical point of view. Regarding the example of Aliseda, it would be valid if it would have been made in the form of a *modus ponens* argument, as follows:

Valid argument (*modus ponens*):
If it has rained or the sprinklers had been on, the lawn is wet. $(A \vee B) \rightarrow C$
It has rained or the sprinklers had been on. $\underline{A \vee B}$
The lawn is wet. C

Here, the truth of the statement that it has rained or the sprinklers had been on establishes the fact of the lawn's wetness, and not vice versa, if we construct a hypothesis about the rain or the sprinklers based on the wetness of the lawn. The opposite character of these two forms of reasoning should be sufficiently clear.

Having said that, the question is that even if the logical basis for abductive reasoning is an invalid *modus ponens*, should we view abductive reasoning as completely useless and dismiss it. The answer, of course, is a definitive no. This is what Peirce has discovered, and also the motive for the rise of abduction in different fields, from the end of the 20th century on, such as in the field of the philosophy of science, medicine, criminology, archaeology, mathematics, and the study of artificial intelligence. The central concept of the latter field of studies is "search", which immediately establishes the connection with abduction.

Deduction, induction, abduction

Let us summarize the characteristics of abduction as a form of reasoning as opposed to deduction and induction. These characteristics appear in a scattered fashion throughout Aliseda's book.

Deduction proceeds from the facts, the premises, to the conclusion. The conclusion follows *necessarily* from the premises. One of the conditions for the validity of deductive reasoning is that true premises must necessarily have a true conclusion, which is to say that this form of reasoning is *monotonic*. Accordingly, deduction as a form of reasoning is truth preserving, meaning that it transfers the truth-value of its premises to its conclusion. According to Peirce, deduction *proves that something must be*. Beliefs have no role to play in this matter.

As against this, **abduction** proceeds from the obvious fact to the hypotheses. Thus, in a certain sense, it is *hypothesis formulation*. What is primarily at stake here *is not the truth*, but explanation. Accordingly, abduction is not truth preserving, and it also cannot be monotonic. If abduction leads to explanations, the consequence is that it will come into contact with the beliefs attached to the explanations with which it is in accord or discord. From this point of view, it is *falsifiable*. As Aliseda writes about abductive explanations: „The trend in logic based approaches to abduction in AI interprets abduction as *backwards deduction plus additional conditions*."[8] Or, the additional conditions mean precisely the conditions of conformity with the beliefs. According to Peirce, abduction suggests that *something may be*, as opposed to *deduction* which, as we said before, proves that something must be.

In the case of **induction**, general statements (conclusions) are inferred from *patterns*, i.e. groups of facts. The conclusions are posterior to the premises and pertain to the future. Therefore, inductive conclusions are *predictions*, as opposed to abductive retroductions. Within abductive reasoning, not patterns, but one-off observations are what matters, proceeding from which we try to advance hypotheses, while discounting all other observations. Inductive conclusions have certain probability degree, which means that they relate to the truth, as it is the case with deductions. As a consequence, inductions are as well *falsifiable*. Nevertheless, conclusions arrived at inductively always contain an element of giving up the whole truth which can be reached by deduction. In other words, neither induction nor abduction is monotonic. As opposed to abductive explanations, background theories matter far less or not at all in inductive procedures. According to Peirce, induction shows that something *actually is operative*.

The logic of abduction

Taking into account the difference between abduction as a process and a product, when ascertaining the logic of abductive reasoning, we view abduction basically as a process. Aliseda expresses this in the following way: "As for the *logical form* of abduction – referring to the inference corresponding to the abductive process that takes a background theory (Θ) and a given observation (φ) as inputs, and produces an abductive explanation (α) as its output – we have found that at a very general level, it may be viewed as a threefold relation:

$\Theta, \varphi \Rightarrow \alpha$".[9]

[8] *Ibid*. p. 40.
[9] *Ibid*. p. 46.

The elements of this logical relation can be comprehended almost intuitively, the only problem is what the sign $\Rightarrow$ means. There are several possibilities for interpretation. Here are some alternatives to consider. It can be interpreted as classical derivability ($\vdash$) or semantic entailment ($\models$) which can be analyzed, to a certain extent, within the well-known classical logical frameworks, in the sense that these can be interpreted in terms of truth values. However, this approach is limited by the fact that it does away with the specific character of abductive reasoning as well as with its innovative contribution brought about primarily by AI research beginning with the 1980s.

However, the possibilities for interpretation do not end here. Aliseda also mentions among them the interpretation as probable inference ($\Theta,\alpha\Rightarrow$ probableφ), in the case of which we may observe that the abductive explanation (α) renders the (φ) observation probable – of course, at a different level. This interpretation differs from the preceding two in that the inference moves from the background theory through the abductive explanation to the facts. In other words, after it is stated, the abductive explanation considers as its objective the factual confirmation of these. Due to this character, it is no longer retroductive, but a forward inference, similar to deduction. Consequently, the widespread interpretation of AI specialists, according to which *abduction is backwards deduction plus additional conditions*, is specified in this form. However, at the same time, if we think about it more closely, they return to the safety and the truth of "good old" deduction. Is this perhaps a case of dealing with the question of time? The treatment of time in deductive inferences is linear and progresses unequivocally from the past through the present to the future, since the conclusion always follows the premises. The process of abductive reasoning should point in the opposite direction, in which the fact, or observation, is followed by the search for premises and the choice between them. The question which follows is how the creation of computers and their subsequent development can render manageable the backward flowing time with software tools in which time flows forward. In fact, the following two interpretations aim at clarifying this issue.

The mechanism of logical programming comes closest to AI developments. In this case, the scheme of interpretation is the following:$\Theta,\alpha\Rightarrow$ prolong φ. Among others, there is the dynamic interpretation ($\Theta,\alpha\Rightarrow$ dynamic φ) in which the interpretation in terms of truth values is replaced by the information change potentials which characterize the doxastic states of agents.

As a conclusion to these attempts at interpretation Aliseda finally states: "Our point here is that abduction is not one specific non-standard logical inference mechanism, but rather a way of using any one of these."[10]

[10] *Op. cit.*, p. 47.

We may have reached a point in time where we must either find correction methods for situations when the so far proposed and certified logical systems break down, or elaborate a logic on completely different grounds and assumptions.

A broader approach to abduction: abductive cognition

Aliseda's account on abduction focuses primarily and almost exclusively on its connections with the development of scientific explanations and with existing theories. Her account relies on the study of artificial intelligence and on elements of the existing logical systems. As a consequence, the most important contribution of her account relies in bringing the study of abductive inference to the field of decision making and in creating the analytical method for its implementation. However, these contributions still remain within the field of scientific explanations.

As opposed to this approach, as we have already mentioned, the book of Lorenzo Magnani, published in 2009, interprets abduction in a significantly broader manner, and therefore, from his point of view, abductive explanation and the logic associated with it are merely a detail.

Magnani differentiates many forms of abduction. According to him, the first necessary differentiation is between *theoretical abduction* and *non-explanatory abduction*. The two types of theoretical abduction are sentential and model-based abduction. This is an important extension to Aliseda's and even Peirce's concept of abduction, which is limited to the field of theoretical abduction. Yet again, theoretical explanatory abduction is extended with the form of non-sentential, i.e. model-based abduction. The construction of this can be either creative or selective. It is selective if the explanation is chosen from existing background theories and creative if we make up the explanation.

The concept of *extra-theoretical abduction* is new within the literature. Specifically, this concept refers to transformations made through manipulative abduction. The leading motto of this is "thinking through doing". This form of abduction can also be creative or selective. However, viewed in this manner, the concept of abduction covers the human condition as a whole and extends to the totality of cognition. This is the origin of the concept of *abductive cognition* introduced by Magnani. "The main thesis is that abduction is a *basic* kind of human cognition, not only helpful in delineating the first principles of a new theory of science, but also extremely useful in the unification of interdisciplinary perspectives, which would otherwise remain fragmented and dispersed, and thus devoid of the necessary philosophical analysis. In sum, the present book aims at having a strong

interdisciplinary nature, encompassing mathematical and logical cases, biological and neurological aspects and analysis of the epistemological impact of the problems caused by the «mathematical physics» of abduction."[11]

Abductive logic maintains its connection to classical linear and monotonic logic, without being reducible to it. The multi-millennial history of European logic is a history of coping with inconsistencies and paradoxes. The names of Bertrand Russell and Kurt Gödel may serve as an example for this interpretation, and one could also refer already to Aristotle or even to ancient Greek philosophy as a whole. Magnani comments on this in the following way: "Moreover, the study of diagnostic, visual, spatial, analogical, and temporal reasoning has demonstrated that there are many ways of performing intelligent and creative reasoning that cannot be described with only the help of classical logic. Abduction is also useful in describing the different roles played by the various kinds of medical reasoning, from the point of view both of human agents and of computational programs that perform medical tasks such as diagnosis. However, non-standard logic has shown how we can provide rigorous formal models of many kinds of abductive reasoning such as the ones involved in defeasible and uncertain inferences. Contradictions and inconsistencies are fundamental in abductive reasoning, and abductive reasoning is appropriate for «governing» inconsistencies."[12]

Let us now turn to the case of visual abduction, to which Magnani's book contains several references. His most important source is P. Thagard. How does he address this question?

Visual abduction

In the case of visual abduction the well-known form of abductive reasoning is used, its peculiarity being that the material is supplied by visual information. The father of abductive reasoning, C. S. Peirce was the one who invented *existential diagrams* which can serve as an instrument for the treatment of visual abductive inferences. Peirce's intention can be summarized as follows: "The major reason for this assessment was made clear from start to finish since Peirce repeatedly stated that his purpose in constructing EG was to build an engine of analysis. As he developed the graphs and applied them to various problems, it was always their experimental possibilities and analytic power that chiefly pleased him."[13*]

[11] Magnani, *op. cit.*, p. x.

[12] *Ibid*.

[13] Roberts, Don D. (1973) *The Existential Graphs of Charles S. Peirce*, The Hague, Mouton, p. 127-128.

[*] For their detailed discussion, see: Gál László, Gál Gabriella: Képi következtetés – műépítészeti esettenulmány, in Egyed Péter, Gál Lászó (szerk.) (2011) *Fogalom és kép 2.*, Editura Presa Universitară Clujeană/Kolozsvári Egyetemi Kiadó, p. 115-142.

However, Peirce did not establish any relationship between existential diagrams and abduction. This is also illustrated by the following quote: "...we know of no text in which he discusses abduction as diagrammatic or iconic. But there are instances of abductive thinking that are most plausibly interpreted as pictorial."[14] This means that we cannot find within his work any solution for the treatment of visual abduction.

Such a solution is attempted in the study of P. Thagard and C. Shelly, cited above. The pretext of the study is based on a paleoanthropological issue. It concerns a skullcap found in the 1950s (Sk54), for which R. A. Dart (1953) advanced an explanation. The skullcap of the australopithecine had been found in a cave at Swartkrans in South Africa. The skullcap had two notches on its left side, which, according to Dart, had been driven into the skull by weapons, probably two arrows. Accordingly, Dart came up with the hypothesis that the hominid had been the victim of murder for cannibalism. Dart's explanation has become known as the "killer ape" hypothesis.

The skullcap has been re-examined by C. K. Brain in 1970. The hypothesis he advanced was completely different. He also took into account the objects found in the cave, among which there were many leopard fossils. The canine teeth from the leopard skull found in the same cave were about the right size and the right distance apart to correspond with the notches on the skull. Furthermore, the place is still frequented by leopards. On these grounds, he advanced a hypothesis according to which the hominid has not, in fact, been the victim of cannibalism, but probably carries on its skull the wounds made by the bite of a leopard. Brain's leopard hypothesis was *simpler and more plausible* than the explanation favoured by Dart.

Both explanatory hypotheses satisfy the conditions of abductive reasoning: they are retroductive, plausible, testable, but economic. It is clear that both hypotheses use visual material in order to advance their explanations. Because the explanations refer to past events, we could call them accounts of *paleoanthropological investigation*. They are situated somewhere on the borderline between criminal investigation and jurisdiction. However, the constructive character is missing, due to which the hypotheses are the result of creative and not selective abduction.

By reason of their being non-sentential, visual abductions, they do not fall under the criterion of truth, which only pertains to sentences. Therefore, Thagard and Shelly cannot choose between the two rival explanatory hypotheses on the basis of truth values. Their choice relies on the criterion of coherence and not on the criterion of truth. According to them, the leopard hypothesis is more coherent (fitting

[14] Thagard, P., Shelly C.P. (1997) Abductive Reasoning: Logic, Visual Thinking and Coherence, in M.-K. Dalla Chiara et al. (eds.), *Logic and scientific methods*, Dordrecht, Kluwer, p. 418.

together) than the "killer ape" explanation. This coherence pertains to the setting of the cave, the size and the distance between the leopard's canine teeth and to the leopard skull found at the same site.

Coherence or truth

The choice between the hypotheses formulated as a result of abductive hypothesizing is made not on the basis of commitment to the truth, but on the basis of *coherence* (fitting together). This is what happens with any form of abducted hypotheses. Thus, whether abduction is sentential or non-sentential, explanatory or ordinary, visual or not, the commitment to the explanation pertaining to the facts is determined retroductively through coherence.

As a result, we necessarily need a more precise concept of *coherence* (fitting together). A more nuanced and precise sense of this concept can be found in another study of P. Thagard: "Coherence can be understood in items of maximal satisfaction of multiple constrains, in a manner informally summarized as follows:

1. Elements are representations such as concepts, propositions, parts of images, goals, actions, and so on.
2. Elements can cohere (fit together), or incohere (resist fitting together). Coherence relations include explanation, deduction, facilitation, association, and so on. Incoherence relations include inconsistency, incompatibility, and negative associations.
3. If two elements cohere, there is a positive constrain between them. If two elements incohere, there is a negative constraint between them.
4. Elements are to be divided into ones that are accepted and ones that are rejected.
5. A positive constraint between two elements can be satisfied either by accepting both of the elements or by rejecting both of the elements.
6. A negative constraint between two elements can be satisfied only by accepting one element and rejecting the other.
7. The coherence problem consists of dividing a set of elements into accepted and rejected sets in a way that satisfies the most constraints."[15]

It is worthwhile to follow Thagard's conception of coherence further. This question asks that we also cite the formal definition of coherence: "More formally, we can define a *coherence problem* as follows. Let E be a finite set of elements of $\{e_i\}$and

[15] Paul Thagard, Karsten Verbeurgh (1998) Coherence as Constraint Satisfaction, Cognitive Science, 22, 1, 2-3.

C be a set of constraints on E understood as a set $\{(e_i, ej)\}$ of pairs of elements of E. C divides into C+, the positive constraints on E, and C–, the negative constraints on E. With each constraint is associated a number w, which is the weight (strength) of the constraint. The problem is to partition E into two sets, A and R (A and R are disjoint subsets of E, where A is), in a way that maximizes compliance with the following two *coherence conditions*:

1. if (e_i, e_j) is in C+, then e_i is in A if and only if e_j is in A.
2. if (e_i, e_j) is in C–, then e_i is in A if and only if e_j is in R.

Let W be the weight of the partition, that is, the sum of the weights of the satisfied constraints. The coherence problem is then to partition E into A and R in a way that maximizes W."[16]

The above formal definition of coherence is important because it offers the possibility of an algorithmic treatment which can then be used for the computerized treatment of coherence and the generation of solution alternatives.

In our opinion, visual coherence plays a deciding role in visual abductive image formation and, therefore, in the process of building design as well as in securing the commitment to one of the proposed designs.

Visuospatial reasoning

Barbara Tversky, Professor at Stanford University, has addressed the issue of visuospatial reasoning in several studies through the years. From her many, frequently tentative, statements we are interested in her opinions on the work of architects: "Initial design sketches are meant to be ambiguous from several reasons. In early stages of design, designers often do not want to commit to the details of solutions, only the general outline, leaving open many possibilities; gradually, they will fill in the details. Perhaps more important, skilled designers are able to get new ideas by reexamining their own sketches, by having a conversation with their sketches, bouncing ideas off them (e.g. Goldshmidt, 1994; Schon, 1983; Suwa and Tversky, 1997; Suwa, Tversky, Gero, and Purcell, 2001). They may construct sketches with one set of ideas, but on later reexamination, they see new configurations and relations that generate new design ideas. The productive cycle between reexamining and reinterpreting is reveled in the protocol of one expert architect."[17]

[16] *Ibid*.

[17] Tversky, Barbara (2005) Visuospatial Reasoning, in K. Holyoak, R. Morrison (eds.) *Handbook of Reasoning*, Cambridge, Cambridge U. P., p. 209-249.

According to the process described here, from the initially vague and undetailed design sketch, through several reinterpretations made with necessary openness and the adding of new ideas, an acceptable design plan is developed, which then has to be worked out in its details.

What interests us here is whether the process described above is abductive. In other words: is architectural imaging abductive? The initial design sketch is a vague idea, which has been worked out creatively. Further analyses and re-examinations, as well as the alterations of the design that they lead to, still represent acts of creativity, which are oriented forward in time. However, the subsequent refinements and detailing refer back to the initial vague design sketch. Now, this already introduces an abductive element, which refers backward. As opposed to the paleoanthropological investigation, discussed above, which turned out to be a case of visual abduction (backward visual inference), visual design in architecture – essentially, architectural imaging – starts with a creative forward inference, which is followed by abductive backward inferences. These lead to a visual image, the final architectural plan, which possibly gets to be built. Of course, all this is done virtually, since it is much easier and economical to experiment with images and merely to assess the possible costs rather than to experiment with the concrete buildings. This freedom is made possible by the human mind.

Visual abduction in architecture

In this part of our study, we will examine, with the aid of a specific example, the characteristics of abductive reasoning emphasized in the preceding part, which are typical for abductive reasoning generally as well as for visual abduction specifically. Our basic aim is to determine in what ways the steps of the architectural design process also contain abductive elements.

The material for our analysis is provided by the design process of Gál Gabriella. Her assignment was to design an archaeological museum for a specific site and architectural context in Cluj-Napoca. The name of the design plan was “archaeological museum of Cluj-Napoca”, which also reveals the basic function to be fulfilled by the building, or possibly buildings.

The archaeological museum of Cluj-Napoca

The first step of the design plan was the assessment of the site and its architectural context. This included taking numerous photographs from which we have selected three.

Fig. 1. Mihail Kogălniceanu Street view from the back of the Reformed church, facing the fortress wall

The street is narrow and architecturally somewhat plain. However, the renovated portion of the fortress wall at the end of the street establishes a connection with the medieval architecture of the city, laying a bridge towards the past.

Fig. 2. Mihail Kogălniceanu Street view from the fortress wall, facing the Reformed church

The second photograph (Fig. 2) shows again the architectural plainness of the street from the opposite direction. Here, the Reformed church from the other end of the street offers yet again the possibility of establishing the connection with the medieval architecture of Cluj-Napoca.

Fig. 3. The surroundings of the site

This photograph (Fig. 3) presents the surroundings of the site. For better orientation, the photograph shows the renovated Tailors' Bastion in continuation of the fortress wall shown on Fig. 1. The two-story building shown on the left houses a lyceum.

These actual photographs of the site reveal the possibilities for the placement of the future building. The digital processing of the ground-space also informs the architect about the possible dimensions of the buildings which can be placed here and the possible form in which they can fulfil their function.

The first digital image was created in many steps. Its potential for further use has vastly increased along with the number of design variations which could be made, helping Gál Gabriella to work up the final optimal design.

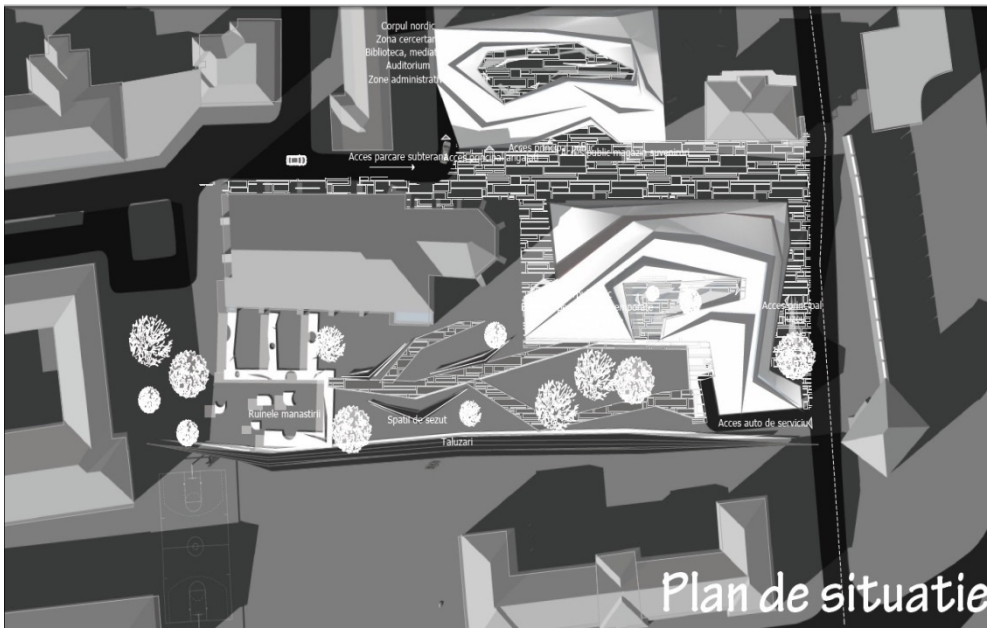
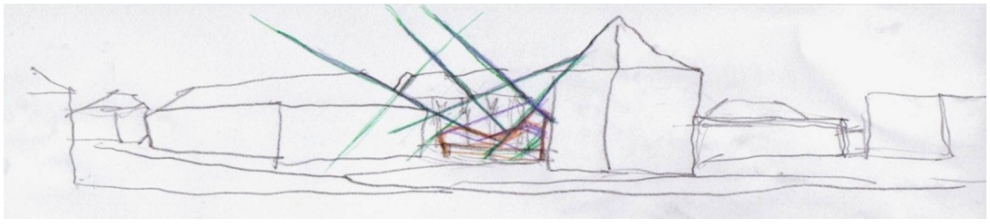


Fig. 4. The digital image of the complete site

The ground plan of the Reformed church seen on the three preceding photographs is shown on the left side of Fig. 4. In front of the church one can see the ground plan of the ruins from the church yard. The right side of the picture shows the renovated portion of the fortress wall, from above as well. The design sketches presented here are not precisely defined proposals, but signify the space where the archaeological museum will be built, i.e. these are the potential building sites. However, the previous three photographs show that some existing buildings will have to be torn down.

After the assessment of the site, Gál Gabriella drafted several sketches. These are freehand drawings.

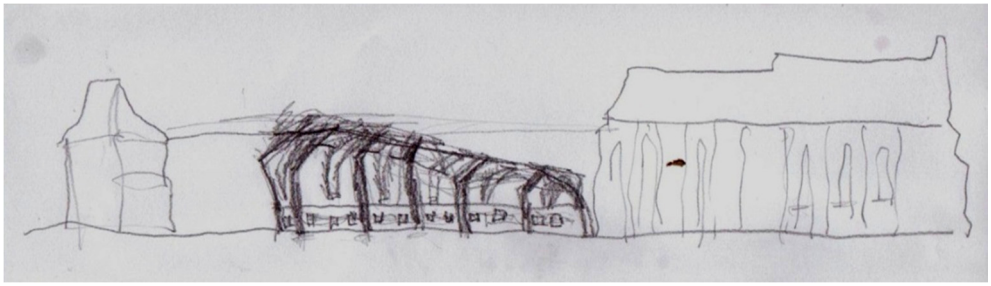


Sketch 1. Fig. 1.

The first sketch examines the roof angles, determined by the angles of the neighbouring buildings, in this case the Tailors' Bastion and the one-storied building on left, which will be kept. According to this sketch, the height relations between the future museum and the existing buildings around it are incorrect, and the new design is not in harmony with the neighbouring buildings.

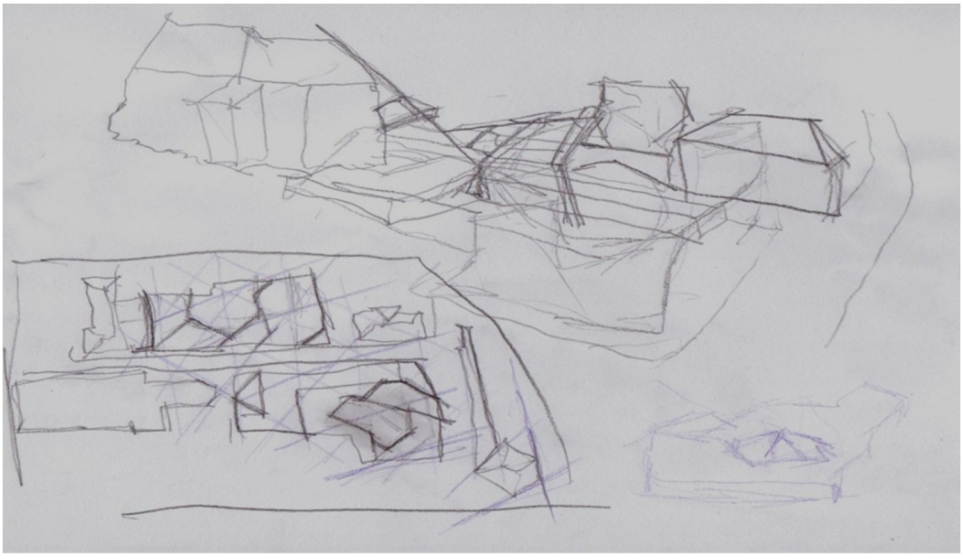
Sketch 1. Fig. 2.

According to this sketch, the Reformed church on the left and the Tailors' Bastion on the right, which serve as a point of reference, demand the heightening of the building. The shape of the building is also more clarified in its design, and its contours get more defined.



Sketch 1. Fig. 3.

According to this sketch, which is the reverse of the preceding one, the part of the new building near the bastion is taller than the end near the church, which means that the height relationship to the church emphasizes the prior building. At the same time, the bastion's volume as a whole takes up less space, and it contains a fewer number of architectural elements, retaining its uniqueness precisely due to its "solitary" character.



Sketch 2. Fig. 1.

The above sketch extends once more the angle of the church roof down to ground level, but it is not clear with what aim. However, the sketch from below has vital significance for the prospective architectural design. The benchmarks are clearly distinguishable: the church on the left, the remains of the bastion wall at the end of the fortress wall on the right. The building site occupies both sides of the street, and this time it also becomes clear that we are dealing with two buildings, one in continuation of the church building, the other in front of it. Now we can realise that, in fact, there are two design projects. From the very start, the sketches take into consideration two alternatives among which a decision can be made.

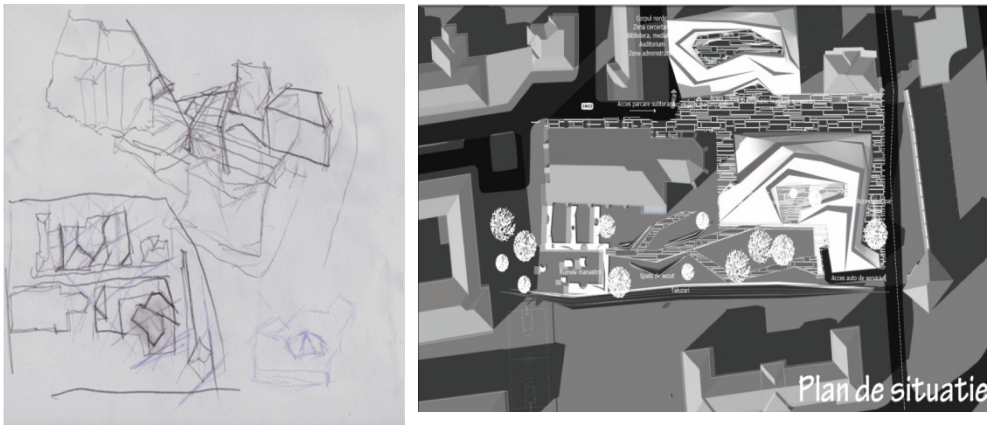


Fig. 5. Comparison between the assessment of the site and the building design sketch

On Fig. 5 we have juxtaposed Sketch 2 and Fig. 4. The latter clearly contains the sketch of the second design plan. One can notice that the drawing from below on Sketch 2 shows those possibilities of insertion into the ground plan which are then digitally reworked. The image on the right is computer made, by reason of which its quality is much higher, the ground plans are much better defined and the views from above as well as the proportions between the buildings are more clearly distinguishable.

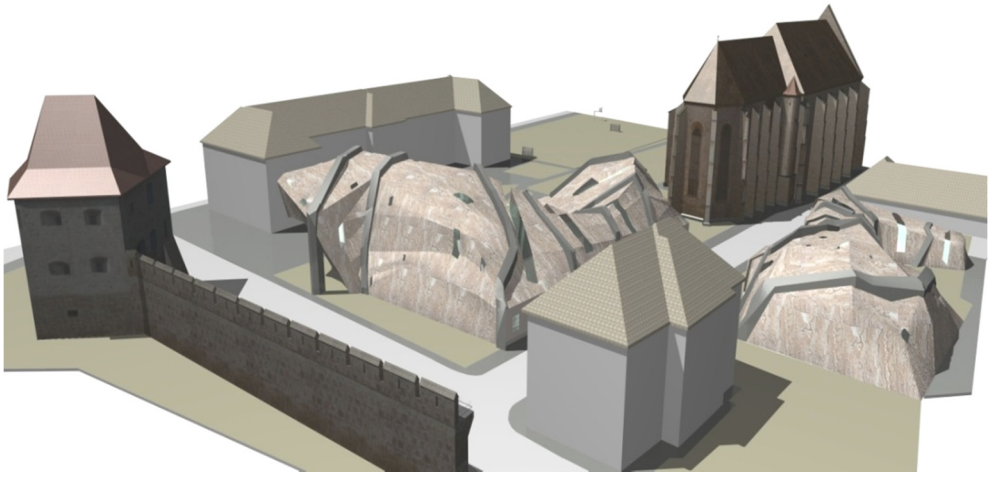


Fig. 6. The rejected design plan

Fig. 6 shows the first design plan. The basic idea of the designer, from which she started, was the *worm*. However, this design plan was rejected on the grounds that it did not fit into the architectural site. The architecture of these buildings does not harmonize with the historical architecture of the surrounding buildings, although the same cannot be said for their material. So, the consonance is only partial. This was the reason for which Gál Gabriella came up with the second architectural plan.

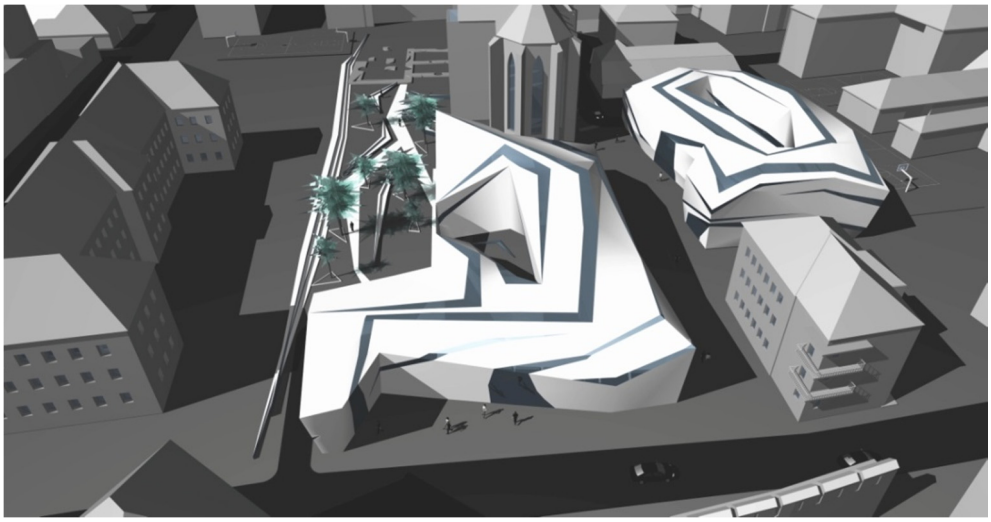


Fig. 7. The general image of Plan 2

The basic concept of the second plan was altered. This time, the starting concept was defined as *stones*. The source of inspiration was offered, in this case, by the surrounding buildings, the Reformed church and the fortress wall, as well as by the construction material of the bastion, fashioned stone. However, the construction material for the new buildings was not stone, given the fact that these had to be 21st century buildings. Nonetheless, the view from above offered by Fig. 7 reminds of the concept of stones with their cracks and irregular shapes. The seemingly haphazard cracks serve, in fact, a very precise function: the “cracks” on the roof are a source of natural light, and those on the fronts of the buildings fulfil a double purpose as entrance and light source. The entrances are of an unusual shape and their design may be, therefore, somewhat surprising.

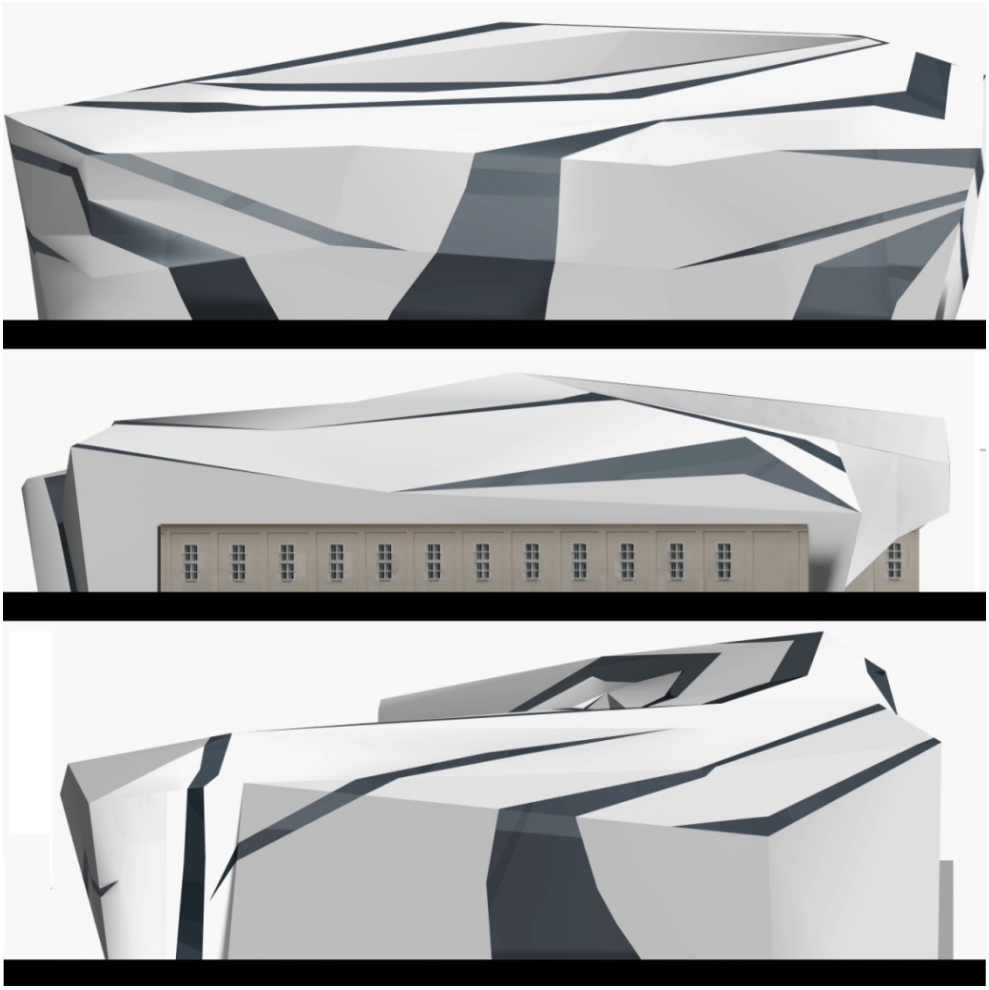


Fig. 8. The fronts of the buildings

Fig. 8 shows three of the four fronts of the buildings. The two upper images are in continuation of the church axis. The view of the front facing Mihail Kogălniceanu Street reveals that a portion of the older building is kept and integrated in this new structure. This helps to conserve the original architecture and atmosphere of the street. The image below shows the back of the building from Mihail Kogălniceanu Street opposite of the church.

Fig. 9. The third front

Fig. 9 offers a view of the front facing Mihail Kogălniceanu Street while also revealing the three entrances of the building.

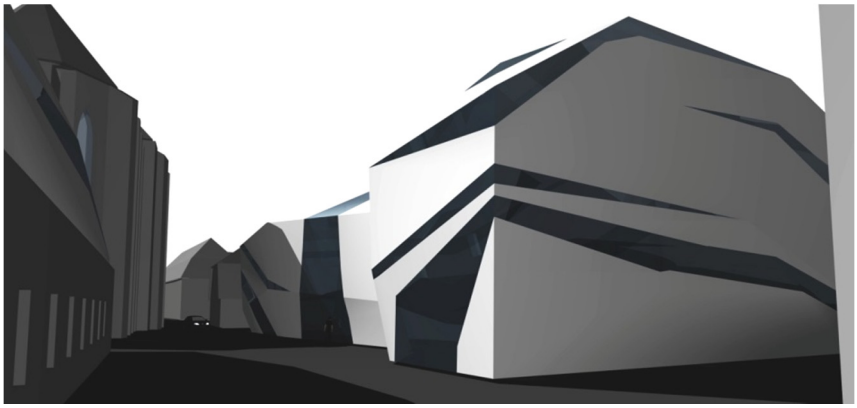
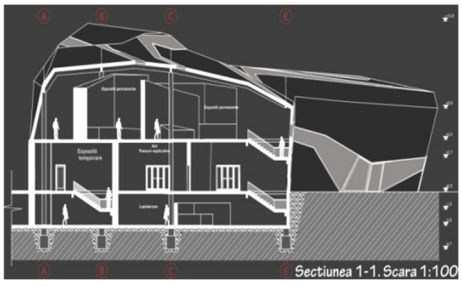


Fig. 10. Virtual view of Mihail Kogălniceanu Street (from the Tailors' Bastion)

In the back of the image, on the left side, we see the Reformed church, so the image displays a larger portion of the building on the right. If we compare this with the Mihail Kogălniceanu Street view shown of Fig. 2, the radical change can be at once seen.



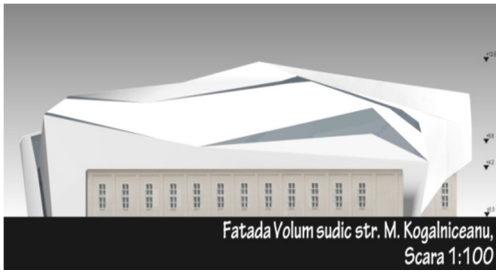


Fig. 11. The interior structure of the building (in continuation of the church axis)

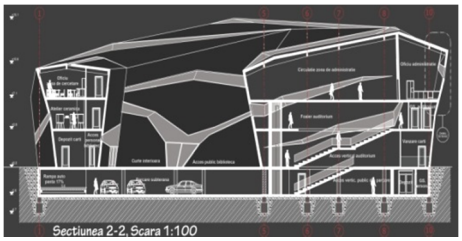


Fig. 12. The interior structure of the building (perpendicular to the church axis)

The two above images illustrate the exterior form of the buildings and their interior structure, furthermore specifying the function of the interior spaces.

The steps in the design of the Archaeological Museum of Cluj-Napoca

Let us now summarize the steps followed by the architecture student Gál Gabriella in the design of the archaeological museum.

As a first step, she was given the name of the project. This then lead to the characteristics which define such a building. She had to mentally elaborate an image of the functions to be fulfilled by the museum building. Her approach was mostly intuitive in this cognitive activity.

In the second step, she had to assess the actual building site with the aid of digital photography. This time, she took hundreds of photos and stored them in the computer, which rendered the photos permanently accessible and modifiable. Meanwhile, she was continually preoccupied mentally with the idea of the archaeological museum.

The elaboration of the digital photographs was followed by the computerized assessment of the site, for which she had to rely on special computer software, which was ArchiCAD. This software was especially designed to meet the demands of architects and enables the creation of visual images and forms with mathematical precision and according to an exact scale supplied by the user. Meanwhile, she temporarily renounced computerized processing and had to choose a leading concept for the design process. The further design process was then lead by the defining characteristics of this concept. The first leading concept chosen by the designer was the *worm*. She had to lay out the building context of this design and shape the new building accordingly in order to fit it into the setting. The most creative freedom needed for this task was offered by freehand drawing. This is how the freehand sketches got made. During the creation of these sketches, Gál Gabriella proceeded creatively. After the idea of the worm has been introduced, she further specified and outlined it (Sketch 1. Fig. 1-3).

The building design seen on Fig. 5 makes use of all the visual optimization tools provided by ArchiCAD. The virtual design process of the building relies upon selective and creative abduction. Why abduction? Because the primary sketches which determined the design plan were drawn freehand. That is to say, the design plan was obtained through abduction from the preliminary rough freehand sketch, reasoning backward from the leading concept of the "worm". Because all this was done through the processing of visual information, we could also say that we have a case of *image manipulation* by abduction.

The reason for the refusal of the first building design was that it did not fit into its surroundings. Thus, the basic value the design plan was correlated with was *coherence* (fitting together), which was missed in this case. The reviewers of the plan invoked coherence with reference to the surrounding buildings, also referring to the city as a whole and its architectural possibilities.

The next step was the outlining of the plan for the second building, while the building site remained identical. Due to this circumstance, the facts established during the preceding steps could also be used; however, the new building design also imposed the necessity to come up with a new leading concept more adapted to the architectural surroundings. This time, the chosen leading concept was "stones".

All the previous steps followed again. A new shape and form had to be designed starting from the computerized assessment of the site. This resulted in a freehand drawing (Sketch 2. Fig. 1) as a start and also represented a creative moment within the design process. After the development of the leading concept, the details of the plan have also been established abductively. These details meant primarily the building shapes outlined more clearly with the computer. The outlines are more detailed than in the first draft due to the fact that the design plan also includes the outlines of the interior spaces of the buildings along with the designations of the functions appertaining to these spaces. Therefore, the abductive backward reasoning does not remain at the level of the shape of the buildings, and abduction reaches a second, deeper level with the design of the building interiors.

How far could this process of detailing go? In principle, it could go on indefinitely. Posing the question this way is all to reminiscent of the question of divisibility in ancient Greek philosophy. However, Democritus' answer was that divisibility has a limit, which has been known since then as the atom. In contrast, computerized building design cannot deal with this question, and even has to consider it as nonsensical. From this point of view, the reasonable question refers to the way in which the building design can determine the structure of the interior space along with the interior objects and ornaments, and even lighting. In any case, the limit is set only by the border of visibility with the naked eye.

Is building design abductive?

Returning now to the concept of abduction introduced by Peirce, let us highlight its main characteristics. First of all, Peirce's concept of abduction pertained only to the development of scientific explanations (hypothesizing) and the choice among them, viz. their acceptance. In order to fulfil this function, hypotheses had to be *promising*, *explanatory*, *testable*, and *economic*, i.e. hypotheses have to be *countable*, and we have to be able to *choose* among them the best one (best explanation) *on the basis of clearly established criteria*.

However, our study did not deal with scientific explanations. We have taken into account L. Magnani's widened concept of abduction and P. Thagard's ideas about visual abduction, together with the efforts of B. Tversky to work out a description of the visuospatial reasoning of architects, and formulated our own *hypothesis* on this basis: *as long as the architect designs images of virtual buildings on the computer screen, his or her designing activity can be viewed as a case of abductive reasoning, since this activity is posterior to the freehand drawing of the first sketches*. In fact, during the design process the architect further specifies, revises and embellishes the concept worked out in the design phase of the preliminary sketches and also harmonizes it with the surrounding buildings. Thus, in fact, the architect is reasoning backward.

The designing process of the archaeological museum of Cluj-Napoca had to correspond in some way to the Peircean concept of abductive theoretical hypothesizing in order to be viewed as an abductive activity. Let us examine this issue more closely.

The initial spatial assessment of the buildings, with the aid of photography and computer imaging, proved to be an activity that facilitated the creation of *promising hypothetical visual images*. This was done in the course of processing of the freehand sketches. Both sketches can be viewed as hypotheses for future buildings, although not as explanatory hypotheses but as models that guide the later stages of designing, and they are of a pictorial character. Because two design plans were developed for the same architectural site, these two plans also represent *two building hypotheses*. They proved to be posterior to the processed sketches, and the possibility of *choice* between them was also given. This choice was determined by coherence. As a result of the choice, the detailing of the second design plan went much further, which significantly increased its *testability*. In our case, this means that the designed buildings are *buildable*. Finally, the last Peircean criterion is *economicity*, which can be assessed by finishing and implementing the design plan. This last step was omitted in this case, as in fact no one would take the risk of experimenting with building and rebuilding edifices of such high costs.

Conclusion

The motivation for writing this study has hopefully become clear from the text. We could add to this that our main objective was to examine whether there is an abductive element in the complex and diversified cognition implied in the design process. In other words, this study is not simply an example meant to illustrate the theory, but an attempt to offer a prospective nonlinear explanation for the way in which the definitive and detailed building plan is elaborated on the basis of a merely "dreamt up and sketched down" architectural design.

(Translated in English by Lóránd Rigán)

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