Abstract. The present study aims to foreground and investigate computational aspects of the design process of Mario Botta’s single-family house in Breganzona. Through the selected case, it mainly addresses the research question, “what are the computational aspects of the examined design process and what is the nature of such aspects?” or, otherwise formulated, “what aspects of such a design process could be formalised, and thus, represented or explained in computational terms?” The study primarily involves analysis and investigation of the “material”; the sketches and the drawings produced during the design process and through this material, reinterpretation, and hypothetical reconstruction of the process. The material is taken as the container of design ideas / concepts and operations, and a formal / conceptual analysis is employed to foreground and extract this content.

Keywords. Design process; design analysis; design computation; design knowledge.

1. Introduction

In architecture, examining past designs is a well-established strategy in studio teaching, carried out for various purposes. A past design might be useful for showing students what a design solution (Ledewitz, 1985), to that degree, a failure, or a non-solution was (Akın, 2002). Past designs are the containers and carriers of architectural knowledge: such content can be distilled, and help students in establishing their own schemata. As it was emphasised by Bryan Lawson (2004) actually, “acquisition of design domain schemata,” is one of the essentials of design education, and design expertise.
Within this context, the present study is based on the following hypotheses: examining a past design could also be useful for understanding computational aspects embedded within a work, and teaching or transmitting such content to the students. This is also true for the designs not originally designed by the help of computers; perhaps examining such designs from this point of view might be even more important to show students that every design has such content, and illustrate to them what content embedded within a design might be represented computationally and how.

From a wider perspective, the purpose of the present study is to question and illustrate how such an undertaking could be employed. The study primarily provides a theoretical and conceptual framework to be adapted to the present situation, and tries to illustrate and discuss how these could be utilised in examining architectural works.

In architectural design research, various inquiries seek models and formalisms for representing design process and design knowledge. A well-known example of such models or formalisms is shape grammars. Such models and formalisms are essential for formalisation, and consequent computational representation of architectural design knowledge and the processes. From a different angle, we may also say that computability of architectural design knowledge is highly dependent upon formalisation and formalisability of such knowledge. The present study may be evaluated within the context of this last issue. It foregrounds and investigates the computational aspects of the material produced throughout the design process of Mario Botta’s Single-family house in Breganzona. The material produced in every stage of the design process is interpreted as embodying a “work” that is frozen in a certain stage of its evolution, with a body of “thought content,” (architectural design knowledge if we prefer) embedded within. Through the examination of the selected case, the study mainly addresses the research questions, “what are the computational aspects of the examined material, and what is the nature of such aspects?” and “what aspects of such a material could be formalised, and thus represented or explained in computational terms?”

2. On the analysis of the design processes

The analysis of architectural design process, with its roots in earlier body of research in general human problem-solving (Newell and Simon, 1972) has been one of the main concerns of the design research society (Eastman, 1973; Akın, 1986). Common to these studies is the “protocol analysis,” a well-established method which is often taken to be “the one that has received the most use and attention,” among “of all empirical, observational research methods for the analysis of design activity” (Cross et al., 1996). The method
“has become regarded as the most likely method (perhaps the only method) to bring out into the open the somewhat mysterious cognitive abilities of designers” (Cross et al., 1996). It was no surprise that in 1994, a workshop on protocol analysis was held in Delft University of Technology, and in 1995, a whole issue of the *Design studies journal* was reserved for discussions on protocol analysis studies.

Despite the popularity and the potentialities of the method, the present study follows a different path, by embracing a different approach. The motivation behind this is the hypothesis that rather than observing and analysing the “verbal reports,” and interconnected behaviour and acts of the designer, examining and analysing the material (i.e., sketches, diagrams, drawings, and models) produced throughout the process might lead to a better, deeper, and more rigorous understanding of the examined materials themselves and the process itself.

The epistemological basis of this argument is so-called evolutionary epistemology, and the proposed method (and approach) refers to Karl Popper’s thoughts on “objective approach” in studying human-made objects.

### 3. Epistemological basis

To use Popper’s (1972) terminology, every product of the human mind, including the works of architecture (or designs) possesses a “thought content” inherent in it. This is the “objective content,” which resides in a design, carried by it, independent from one’s experience of it, and even independent from its creator’s original intentions and thoughts invested in it. Thought content is not the essence of a design, since a design may carry and yield “thought contents” which nobody has thought so far (including its creator), and perhaps nobody will ever think about; a content of a design may well go beyond what was operational in its creation. Such content is only accessible if one is able to read and understand a design, and one has the ability to decipher and grasp the content embedded within: one always comes with his or her horizon of expectations, a frame of reference, to be applied to the present situation.

Popper distinguishes between two main categories of problems arising from the study of the products of the human mind. The first category is primarily related with the way the maker or creator of such products behaves while constructing the products. Apparently, here, the primary emphasis is on the methods, and the “problems concerned with the acts of production.” On the other hand, the second category is primarily related with the things or objects themselves, and all the related attributes such an object might carry or subject to. This is what Popper (1972) calls an “objective approach,” which puts the primary emphasis on the “objects themselves,” isolated from their makers and
the acts and behavioural dispositions operational in their making. Popper’s point is that such examination of objects themselves might lead us to develop a better (and objective) understanding of them; more important, it may shed light on the way they were produced, and the methods, even the production behaviour operational in their production.

4. Assumed design model

In the analysis, the so-called conjecture / analysis model of design was assumed. The assumed model was first conceptualised in Bill Hillier, John Musgrove and Pat O’Sullivan’s (1972) seminal paper titled “Knowledge and design.” In their conceptualisation, design was viewed as “essentially a matter of pre-structuring problems either by a knowledge of solution types or by a knowledge of the latencies of the instrumental set in relation to the solution types.” Conceiving approximate solutions early in the design process helps the designer to “understand the problem,” and these approximate solutions work as departure points to initiate the design process, something to work with, to develop, and to evaluate. In their conception, one of the primary emphases was on the “developmental” aspect of the process: “The variety of possible solutions has been reduced to one unique solution by some means. The succession of documents produced during design reflects this progressive reduction of variety. More and more specific drawings for example exclude more and more detailed design possibilities” (1972). In this sense, the “solution in principle” conceived early in the process is “progressively developed and refined (or discarded)” (1972). Such an assumption was essential in the analysis, since it provided a basis, a set of preconceptions, a schema to carry out a structured analysis and understanding of the examined material, and hypothetical reconstruction of the process.

5. Investigation

The selected case for the analysis is the single-family house in Breganzona, one of Botta’s relatively late designs (figure 1). The primary rationale behind the selection of this design is that stages of its design process are recorded in the form of sketches and drawings, following a sequence, and the provided material is well enough and relevant to support and illustrate the present argument and in developing a fruitful, content-rich discussion.

The design of the single-family house in Breganzona begins in September 1983 and ends in October 1986. In the present analysis, the sketches and drawings; the “material” produced during the design process is investigated chronologically, each design variation, each design stage with reference to
each other and to the overall process, to reconstruct the design process, and to foreground and formalise the computational aspects within each stage, between the produced variations and between the stages.

Methodologically, in the study of the material, and in the examination and reconstruction of the formative processes operational throughout the process, a formal / conceptual analysis is employed. The primary reference of the formal / conceptual analysis refers to the line of thought beginning with Colin Rowe’s (1977) “The mathematics of the ideal villa” of 1947, and Peter Eisenman’s (2006) doctoral dissertation, *The formal basis of modern architecture*, of 1963.

Here, in the investigation, what is mainly important is to not only to determine how the form emerges or comes into existence through the process, but also to determine which factors contribute to this formation, in what respects. The findings can be summarised as follows:

5.1. GENERAL OBSERVATIONS ABOUT THE EXAMINED DESIGN PROCESS

Contrary to the often-accepted view, throughout the process, the design did not merely proceed from a less detailed to more detailed (or refined) version. Actually, each stage contained a set of less detailed and more detailed proposals. Otherwise formulated, we may say that the process does not refer to a single “developmental” line, from a less detailed towards a more detailed description of a design, but might also involve a series of interconnected parallel lines of search in various detail levels.

We may say that there are two categories of formative elements, concepts, or ideas operational in the observed process. The first category refers to the concepts, or ideas that are in formative control of the designed object and the subsequent set of elements and concepts. These might be named as “dominants” or “dominant formative elements.” The rectangular solid controls the overall outer form (and the outer overall effect) of the design, the square frame controls the outer boundaries of the plan and the spatial organisation, and finally a grid structure (often a nine-square grid or a modified version of it) is in formative control of the inner order and the spatial organisation. The
second category refers to second-order (minor) elements, concepts, and ideas or elements, such as apertures, entrances, which have formative affect on the design, and such as the diagonal axis, which is in control of the circulatory spaces. Despite their formative contribution to the overall design, such entities are under the control of the dominants.

5.2. VARIATIONS AND INHERITANCE

Throughout the process, between the stages, many ideas, concepts, or elements, whether dominant or second-order, are inherited from one stage to another, sometimes kept as they were, sometimes modified. Conceptual inheritance, operational throughout the process, was an important finding of the investigation (figure 2).

Throughout the process, major or minor variations are produced to be integrated / incorporated into the design (figure 3). Such variations are controlled by the specificities (or conditions) provided by the problem situation, and the design itself. The minor variations do not refer to operations in the formative sense, but rather introduction of new minor ideas, concepts, or elements to the design. The elements are integrated to the overall configuration, if successful, to be inherited to the following design stages, while unsuitable (unfit) variations are filtered out to single out the preferred ones. Actually, this was an indication of the existence of “trial and error” (or, if we prefer, conjecture / analysis) process residing behind such a process. As one will recognise, the pattern is operational not only throughout the process between major trials (as the proponents of the conjecture / analysis model of design would accept), but also within each stage and variation whether minor or major. There were trials, in various levels and with different characteristics, such as introduction (and evaluation) of a number of entrance variations, spatial organisations, apertures, etc. superimposed on the overall design and evaluated by the conditions of the present design situation.

5.3. FORMATIVE PROCESSES WITHIN THE DESIGN STAGES

As it was argued by Eisenman (2006, 81), “all specific architectural form can be related to a generic antecedent.” Here, generic antecedent or form refers to a universal, transcendent form with its own inherent laws. It is an absolute, which “cannot be considered subjectively” (2006, 81) Specific form, on the other hand, refers to the actual physical configuration, realised to be met a set of conditions relevant to a specific design situation, such as context, program, requirements, function, and so on. Consequently, determination of the generic antecedent is essential to determine the conditions within which
the design-under-investigation was embedded, and the way these conditions affect the formation of the design. As one would recognise, this is fundamental for the analysis of designs and the design process. Once a generic structure is determined, the formative process that transforms the generic to specific can be hypothetically reconstructed, and the conditions such a process is being affected, may be identified. Such a hypothetical reconstruction might not refer to the actual (trans)formation process. However, for that reason it may well go beyond the apparent content of the original material, and the reconstruction may become a creative act itself.

Figure 2. Transformation of the design from Sept. 1983 to Dec. 1983. Inheritance and transformation of the dominants.

In the investigation, all the stages are reconstructed, representing the transformation of the design(variation) from a generic state to a specific state (or, if we prefer from a generic form to a specific form) (figure 4). These reconstructions not only showed the computational (or algorithmic) nature of the transformations and formative operations but also the set of principles, rules, dimensions operational in this (trans)formation (figures 5 and 6). This was one of the important outcomes of the study as a means of illustration of the content embedded within the process, which can be formalised and computationally represented.

6. Final remarks

The outcome of the investigation yields a set of findings, some of which are related to the computational aspects of the process and the examined material. The primary outcome was that despite the fact that the computer is not used during the actual design process, the process and the material have strong
computational aspects, and actually, behind the process lies a design thinking / reasoning with a strong computational emphasis.

Perhaps the second important outcome was the implied framework, which comes out of the findings and observations summarised particularly in sec-
tions 5.1 and 5.2. The framework could be used as a basis for developing models and might be turned into a formalism that could be developed further and used for this purpose.

It may be said that the implications of the present study might well go beyond the scope of the present study that was set at the beginning of the paper. For example, the proposed and elaborated theoretical and conceptual framework could be used as a basis for developing CAAD software / tools.

Finally, it must be emphasised that the scope and limitations of the present study do not allow for more. However, it actually points to an epistemological, conceptual, and methodological framework, and a set of findings and issues to be questioned and reconsidered as a basis for further research.

![Figure 5. Formative operations: hypothetical reconstruction (Sept. 1984 stage).](image1)

![Figure 6. Formative operations: hypothetical reconstruction (July 1984 stage).](image2)

**Endnotes**

1. Schemata are one of the basic ideas of cognitive theory referring to “an internal representation of the world,” which consists of “an organization of concepts and actions” that are used for perception, observation, thinking, judgment, learning, understanding, interpretation, problem solving and creation. Referring to cognitive theory, learning can be interpreted as building an intellectual organisation of such concepts and actions that is called a schema (Grider, 1993). A schema can be revised and expanded by new information. Within the context of architectural design, a schema is essential for conceptualising new designs as well as judgment and evaluation.


3. Compared with the “protocol analysis” such an approach is rare. As far as I know, Alan Dubois (1987) employs a similar approach in his investigation of the materials produced throughout the design process of Le Corbusier’s Villa Garches, although his main departure point and purpose is quite different from the departure point and purpose of the present paper.
4. The term roughly refers to expectations, but also problems, prejudices, previous knowledge, and all such, elements of schemata which affect understanding and judgment of things those are external to us.

5. The term roughly refers to expectations, but also problems, prejudices, previous knowledge, and all such, elements of schemata which affect understanding and judgment of things those are external to us.

References

Dubois, M.: 1987, 2 into 1, Architectural review, 1079.