

# Dissecting Design: Exploring the Role of Rules in the Design Process

by

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## Abstract

Since the first application of computer programs to problem solving in the 1960s, computers and computational processes have been gradually introduced in the field of architecture to the point where today they are an inherent part of architectural practice and education. This extensive use of computers in architecture, however, occurs late in the design phase, at the stage of production of construction documents or representation of the final product, and so rarely are computers used to address the early design phase, that of creativity. A significant reason for this is that computational processes, based on algorithms, use explicit rules and unambiguous procedures, while the processes that architects employ at the early design phase are implicit and obscure. Whether a process is implicit or explicit, though, it is still underlined by a framework of interacting rules. Can rules, therefore, provide a bridge between explicit and implicit processes? The present research addresses this question through a design experiment with a group of professional architects. The experiment was in design composition from scratch and the scope was to identify the role of rules in the architects' design processes. In this framework a shape grammar formalism was developed to describe both the design activities and the end products. Architects were found to work towards a design solution by developing general rule schemas that gradually take the form of specific and explicit rules. It was also observed that this process is constantly informed and enhanced by the emergence of perceptual design events.

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## **1. Introduction**

During the past three decades the term computation emerged in the center stage of architectural design discourse. This was a direct outcome of the increasingly extensive use of computers in architectural design. Computation, however, describes the act of combining symbols according to certain rules and so does not necessarily connect to a computer, but could also be implemented by hand. Problems are thereby solved by using algorithms; sequences of rules that lead to a solution through a finite number of operations. Such operations could be prescribed for any design environment, being pencil and paper, computer, drawing board etc., and so would still constitute an algorithm. Nevertheless, computers are highly favored due to two main advantages that relate to time-saving: results are quickly produced, and variations can be rapidly tested.

It is precisely such time saving advantage that led architects to adopt both computational processes and computers in design. Today, computational processes are widely used in design but more so in its later phase, this of the production of construction documents or representations of the final product. In fact, computational processes are scarcely used in the early design phase, the time period that starts the moment the architect is given the design problem until she reaches a satisfying solution, due to the distinct nature of the design problem and the design process. Design problems are ill-defined, ill-structured, or wicked (Rittel and Webber, 1973), which means that all of the necessary information is not, or even cannot be, available to the problem solver. The design problem needs to be structured upon objective and subjective parameters, for example the program for a building and the personal interpretation of the program respectively. Therefore, architectural design problems cannot be organized deterministically. This special feature of the design problem affects the design process, and so the later cannot follow an explicit path to reach the final product and is instead characterized by the use of implicit rules. The creation and use of such

rules is further sustained by the designers' solution-focused processes (Lawson, 2006), in contrast to the scientists' problem-focused processes. Lawson's (2006) studies on design behavior also revealed that architects learn about a problem and arriving at a solution through a trial-and-error process, whereas scientists focus on studying and analyzing the problem to discover the underlying rules. As a result, architects do not have a clear design process to lead them from the design problem to the creation of a synthesis of form.

Creative design processes involve rules that according to Schön (1988) are "largely implicit, overlapping, diverse, variously applied, contextually dependent, subject to exceptions and to critical modification." Computational processes, on the other hand, require unambiguous and explicit rules, that to architects appear as too rigid, sacrificing function and meaning, and excluding innovation as created through ambiguity, turning design into a mechanical process. In other words, explicit procedures are seen as threatening two of the main characteristics that support creative design, ambiguity and emergence, by limiting architects' ability to depict new relationships in a design representation, re-interpret them and further investigate the solution in a novel design. Explicit rules diminish the trial-and-error process that architects have been using for centuries. Ivan Sutherland (1975), was among the first to realize that the above perception relates to how the different representational media affect the design process. For example, pencil and paper have no inherent structure; they can be decomposed and manipulated in any manner of interest to the designer. An evolving design may thus have alternative descriptions that can change from time to time in unanticipated ways. The structure of computer design, however, presents an obstacle to all of this, since it is fixed in specific design operations. While computational processes, based on algorithms, use explicit rules and unambiguous procedures, architects at the early design phase employ processes that are implicit and obscure.

Whether a process is implicit or explicit, it is always underlined by

a framework of interacting rules. This observation led me to express my first thesis question: can rules provide a bridge between the explicit processes that computers demand and the implicit processes that architects employ at the early stages of design?

As I started considering the different characteristics of rules in design, another question naturally arose: where do these rules come from? In order to provide answers to the above questions I began to explore the features that affect the design process. During this exploration I realized that constraints constitute significant design parameters that determine both the design process and the final outcome. My question was therefore transformed as follows: how do designers form rules to respond to the design problem's constraints?

To address this question I investigated the design processes that practicing architects employ in the early phase of design with a case study experiment. The experiment focus was in design composition from scratch. Twelve professional architects from the research group Affinities and work at the Architectural firm Bergmeyer in Boston participated in the experiment.

The method used in the experiment was a protocol analysis of the subjects' design thought process. The experiment consisted of three tasks: two design tasks and one reporting task. In each design task the participants were asked to solve a design problem in a one-hour session. They were not asked to describe their moves and actions while they were designing, nor were they interrupted during that time. The two design tasks happened sequentially over a two-day period. One week after the design tasks were completed, the reporting task followed. I met with each participant and together we reviewed the process he/she followed with the aid of the videotapes.

The two design tasks were drafted as two versions of the same problem so as to incorporate the idea of constraints in the experiment. The two versions differed from one another in terms of the levels of constraints. In both cases the client (a four member family), and the size

of the site (16.5f x 100f) remained the same. The two problems differed with regards to site location (the first in Chicago and the second in San Diego), program specification (precise in the first case, free in the second), and building code (a two story limitation on the first problem, no height restriction on the second). My initial hypothesis was that, in the comparison of the two solutions, I would be able to identify the ways that architects form rules around constraints and also extract types of these rules.

The completion of the experiment was followed by analysis of the design solutions. For each architect and each design solution the design process was segmented in three categories: organization, actual design and final solution. This was followed by an attempt to categorize the twenty four design solutions in different groups regarding the design activities that each architect employ around constraints. Finally, a shape grammar formalism was used to describe each design procedure and result. Throughout the above process, I was constantly trying to identify perceptual design events, that is events that relate to the feedback relationship that informs and enhances design activity.

The discussion on the design solutions revealed that architects create frameworks around constraints, problem or personally oriented that take the form of general rule schemas. These rule schemas are applied in the design process and gradually become explicit and definite rules. In that sense while rules play a fundamental role during the early design process, they reflect qualitative descriptions rather than specific definitions of the object under construction and so contradict with the explicit character underlying most computational processes. Another important conclusion was that perceptual design events constitute an essential characteristic of the design process. These events relate to emergence and constantly inform design through a feedback relationship based on what the architect sees in her drawings. The strict relation of the perceptual design events with the architect's seeing action results in their unanticipated emergence, a characteristic that creates many

questions around their possible automation.

The thesis is divided in four chapters. In the first I offer an overview of the notions of design problem and the feedback relationship and how they affect the design solution architects develop during the early stages of design. These two conditions are presented in the context of the systems and rules that describe their structure and performance. The chapter is concluded with a discussion of rule-based processes in design and in particular a description of shape grammars.

The second chapter elaborates the experiment process: the basic concepts that formed the experiment's context; the participants; and the design problems that they were asked to solve. The analysis of the design solutions is presented in the second part of the chapter. An extensive analysis of the protocol studies is illustrated and the three groups of design activity are presented.

Three examples of design activity, one from each group, are then presented in the next chapter. These demonstrate how the shape grammar formalism is reached in each case.

Finally, in chapter four three cases of perceptual design events are detailed and presented. Their contribution in the design process is demonstrated.

The thesis ends with a discussion of the results of the case study.

## 2. Background

In 1945 J. Presper Eckert and John W. Mauchly developed the first modern computer at the Moore School of Engineering, University of Pennsylvania: the ENIAC (Kalay, 2004, p.28).

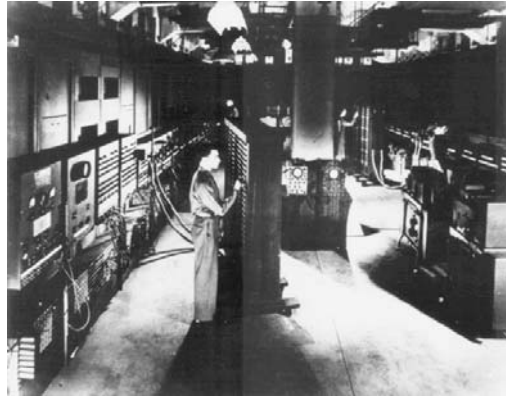


Figure 1: The ENIAC

Since then, the development of modern computers has been rapid. At the beginning these technological innovations were related to and supported by the military needs of World War II. It was only after the end of the war that the use of computers expanded to other fields, so as to meet economic, scientific, social and political needs (Kalay, 2004, p.28). In the field of architecture, the pioneering work of Ivan Sutherland in 1963 reflects the “waltz” of the period. The creation of *sketchpad* (Figure 1), an innovative computer program, introduced a new way of interaction between man and machine, as well as initiated computer-based design.



Figure 2: Ivan Sutherland demonstrating the sketchpad

Since then, computer systems have been gradually introduced to architectural design practice and education, reaching a point where today they are widely used.

The extensive utilization of computers in architecture was followed by the emergence of the term “computation”, used to express the processes that take place inside the computer. Computation, however, describes the act of combining symbols according to certain rules and so does not necessarily refer to a computer, but could be hand-implemented instead. Problems are solved in a finite number of steps through the use of algorithms, that is, a “finite set of rules or operations that are unambiguous and easy to follow” (McGill, 2001). Such operations could be prescribed for an architect designing simply with pencil and paper, and so would still constitute an algorithm, that is, a computational process. The use of a computer to execute an algorithm, though, is favored due to two main advantages that relate to time-saving: results are quickly produced, and variations can be rapidly tested.

This advantage of saving time led architects to adopt both computational processes and computers in design. Today, computational processes are extensively used in design, but more so in its later phase, that of the production of construction documents or representation of the final product. In fact, they are scarcely used in the early design phase, the phase that describes the designer’s actions from the introduction to the design problem, through the exploration of the possible solution alternatives and their transformations, to the crystallization of a first satisfying design result. A basic feature of the architectural design process at this stage, which hinders the use of computers is its undefined and unclear character: designers seem to proceed, in seeking design solutions, in a rather “ad hoc” way (Cross, 2006) that makes difficult the establishment of systematic methods of approaching the design problems. Architects apply ad hoc design processes to respond to two unclear design conditions: the undefined character of the design problem and the ambiguous nature of the feedback process, the process that

informs and guides architects' actions. The unclear character of both conditions relates to the coordination and codification of the available design information, which is contained in the design problem in the first case and included in the design itself in the second.

As the purpose of the present thesis is to provide insight into how architects develop design solutions during the early phase of design; the two conditions of design problem and feedback relationship are introduced and further analyzed in the next sections. The two conditions are presented with respect to systems and kinds of rules that describe their structure and performance.

## **2.1 Design Problem**

In his research on computational approaches to architectural synthesis, Sotirios Kotsopoulos quite rightly selects and uses Newell and Simon's conceptualization of the workings of design questions. According to them *"a person is confronted with a problem when he wants something and does not know immediately what series of actions he can perform to get it"* (Kotsopoulos, 2005). Depending on the type of problem, the path to the solution can be easier or harder. A common distinction between problem types is expressed by the following two categories, which are mutually exclusive and completely exhaustive: well-defined and ill-defined problems (Simon, 1984). In the first category belong problems that scientists or engineers deal with, which are definable and may have solutions that are findable. In these problems, usually the mission is clear, such as, for example, finding the solution to an equation. Furthermore, an exhaustive formulation can be stated containing all the information the problem-solver needs for understanding and solving the problem, provided that he/she knows how to do it.

On the other hand, this is not the case for problems that are ill-defined, ill-structured, or "wicked" (Rittel and Webber, 1973). These problems have neither clarifying traits, nor a single solution. The problem space is not defined in any significant way and so the necessary



information about the problem is not, or even cannot be, available to the problem solver. In other words, the information contained in the problem may change at any time by the introduction of new elements or by the addition of forgotten ones – a fact that alters the solution possibilities. As a consequence, ill-defined problems do not have an explicit basis of termination, a “stopping rule” determining the end of the process does not exist (Rittel and Webber, 1984). Another characteristic of this type of problems is the absence of concrete solution criteria. As the requirements are vague and the characteristics of the end product are unclear, there is no single solution to the problem, but rather a plethora of different ones. Additionally, this absence of solution criteria forms another characteristic of these problems; the developed solutions are not necessarily correct or incorrect and at any moment another reasonable solution may be proposed. Ill-defined problems are, thus, structured by both objective and subjective parameters.

Design problems can be categorized as ill-defined problems, since usually they involve judgments and impressions that are based on architects’ beliefs rather than on external facts. The objective parameters of design problems are filtered by the subjective view of the architect: the program for a building and a personal interpretation of it, respectively. An example that illustrates well the ill-defined nature of the design problem is that of a design competition. A plethora of totally different design solutions is proposed as an answer to the same program, the same site, the same time frame, and the same client. Although the design problem is the same, the path to each solution is totally different; it involves distinctive interpretations of the requirements and evolves in a non-linear way. In that framework design problems cannot be organized deterministically. This special feature of the design problem affects the design process, which accordingly cannot follow an explicit path to reach the final product and therefore is characterized by the use of implicit rules.

In the above labyrinthine path, the act of interpreting and

combining the design problem requirements in a unique and interesting way is considered to be a major work of creativity. An important feature that serves as an impetus to the above creative process is the feedback relationship between the actual design and the architect's thoughts. The characteristics of this relationship and the factors that affect it have a major impact on the design outcome, as they enhance or hinder design exploration by allowing, or not, different levels of interpretation and reinterpretation.

## **2.2 Feedback Relationship**

*"Creative fields are characterized by the generation and manufacture of objects for reflection and evaluation." Donald Schön (1990).*

The most challenging and enjoyable aspect of architectural design occurs during the early phase of design, when the architect is still free to play with concepts and shapes while exploring different ideas to solve a design problem. During this process, a variety of tools and procedures can be used to actualize architectural objects as possible solutions to the design problem. The goal is to develop a representation that can most accurately illustrate the designer's thoughts, while at the same time leaving enough space for further investigation and exploration. As Donald Schön states, the construction of objects for reflection is what characterizes creative fields (Schön, 1990). The generation and manufacture of an object, however, is not actualized in the same way in all creative fields. On the contrary, as Robin Evans notes, there exists a *"peculiar disadvantage under which architects labor, never working directly with the object of their thought, always working at it through some intervening medium, while painters and sculptors, who might spend some time in preliminary sketches and maquettes, all end up working on the thing itself"* (Evans, 1997). Throughout the whole design process, architects model an object that is not yet realized, using different kinds of processes and representations in order to illustrate its form and

understand its structure. The object comes to life through the model, and the interaction between model and object leads to a constant exchange of information between the two, until the culmination of the design process in the realization of the object.

In the above context, architectural design can be perceived as a conversation between the designer's thoughts and the object under construction. An important feature that determines the outcome of this conversation is the feedback relationship between the two. The feedback relationship describes the process that informs and guides the designer's moves and actions, while working towards a design solution. In architectural design feedback strongly depends on *seeing*. The architect proceeds with the design solution based on the relationships that he/she detects in the design. Reinterpretation of existing forms and shapes in design reveals, each time, new directions to the solution. The emergence of new shapes, in other words, allows new forms to exist and thus enhance creativity.

Several studies based on protocol analysis have acknowledged the importance of reinterpretation and emergence in the early phase of design and tried to identify mechanisms and tools that support it. Studies have also examined the role of sketching in reinterpretation, as well as discovered the kinds of interactions that architects have with their designs that supports emergence. In a series of papers, Gabriela Goldschmidt has examined protocols of design observing both novice and expert architectural designers. She has proposed that the dialectic between arguments of "seeing as" and "seeing that" during the process of sketching "allows the translation of the particulars of form into generic qualities and generic rules into specific appearances" (Goldschmidt, 1991). Along the same lines, Schön and Wiggins suggested that sketching constitutes a visual representation that can potentially be perceived in different ways through a design process that develops along the schema see-move-see (Schön and Wiggins, 1992). Goel reversed the question and investigated the properties of sketch that allow for

reinterpretation. He acknowledged the importance of “lateral transformations” (Goel, 1995) and supported the hypothesis that because sketching constitutes a symbol system, which is characterized by syntactic and semantic denseness as well as ambiguity, it allows lateral transformations to occur. Symbol systems, however, that are non-dense and unambiguous will hamper the exploration and development of alternative solutions and force premature crystallization of design development.

Goel's conclusion on ambiguity is similar to an observation made by Ivan Sutherland back in 1975. Sutherland's comment concerns reinterpretation relative to the structure of the design in different representational media. In his own words, *“The usefulness of computer drawings is precisely their structured nature and this structured nature is precisely the difficulty in making them”* (Sutherland, 1975). During the conceptual phase, for example, a design component may carry various meanings and could be interpreted in many different ways: a line may signify a wall, a groove on the ground, a division between two spaces or a direction. *“But ambiguity is conspicuously absent from design when it is computer aided, even in the basic case where designs are given in line drawings”* (Sutherland, 1975). Sutherland argued that because pencil and paper have no inherent structure, they can be decomposed and manipulated in any manner of interest to the designer. An evolving design may thus have alternative descriptions that may change from time to time in unanticipated ways. The structure of the computer design, on the other hand, presents an obstacle to all this, because it is fixed in specific design operations.

The description of the design becomes a crucial issue. Computers and symbolic systems demand a clear and explicit description of the design: definition of a vocabulary of units and a set of rules that determines their relationships. The definition of a unit signifies that a specific meaning is attached to it, a fact that automatically excludes other possible meanings that the unit could have in different

contexts. While this could be the case for a fixed design solution, that is, the end design product, it cannot apply to the designs produced during the early phases, where meaning constantly changes. What algorithmic definition could describe these continuous changes? What the above protocol studies have shown is that this continuous change of meaning, this reinterpretation of the designs based on what architects see in them, constitutes the core of the feedback relationship which enhances creative design: *“what you see is what you get”* (Stiny, 2006). What is still undefined and unclear is the role of rules in this feedback relationship of seeing. The algorithmic processes that connect seeing with units and rules remains to be discovered in the design processes that architects employ while working towards a design solution.

### **2.3 Design Process and Rules**

*“It is no good predicting what people will see and do next unless it shows how they are free to go on in another way.” Stiny (2006)*

The struggle to find design methods to address the vagueness of the design process has been a source of irritation and delight to architects for the past two and a half millennia. Various design methods were developed to address the unpredictability of design and its non deterministic character.

Rule-based design is one of the oldest methods, which, due to its characteristic of well capturing explicit processes, is widely applied in the construction of computer programs today. The method basically provides a “recipe,” an algorithm, that instructs designers on the completion of a task. There are two basic components of this design method: a vocabulary of units or parts, and a set of rules that define their relationships. An adequate description of these two components to effectively address design complexity and ambiguity represents what architects have tried to do since the oldest recorded use of the method, in Marcus Vitruvius’ “Ten Books of Architecture,” (Kalay 2004), until its

newest use in computer design software of parametric design and scripting. The task is not an easy one. A clear definition of the vocabulary of parts and the set of rules could easily turn design into a mechanical process by excluding ambiguity. From the development of the rule-based methods in design to the creation of the first computer programs for problem solving in the 1960s, the threat of oversimplification and mechanization of design was obvious.

Christopher Alexander (1964), pioneering the field of computational/systematic design methods in his book “Notes on the synthesis of form,” he describes design through structures of sets. In each set, elements have some reason of being together. These sets form systems and subsystems, which are connected through tree hierarchies that define the dependencies between them. While this design method is very appealing with its clarity this systematization in strict hierarchies fails to address the non-hierarchical design structure. Therefore, many pioneers rejected design methodology in the 1970s. As Nigel Cross mentions in his article “Forty Years of Design Research,” Alexander stated *“I’ve disassociated myself from the field...There is so little in what is called ‘design methods’ that has anything useful to say about how to design buildings that I never even read the literature anymore”* (Cross, 2007). The reaction against design fragmentation was due to early attempts to divide the whole into logical parts. In other words, the desire to categorize and predict design actions and moves was in conflict with the basic characteristic of design, that of unpredictability. Thus, rule-based design methods must account for the parts and the set of rules that relates them because *“descriptions fix things in computations, and nothing is ever more than its description anticipates explicitly.”* (Stiny, 1994). Design constantly changes based on what designers see; designers use the same elements in different relationships or introduce new elements in existing relationships, or change the relationships. The description of design parts and rules should be flexible enough to allow all the above situations to occur, and allow for reinterpretation. But which

type of computation would allow the above situation to occur?

In the article “Classical and Non classical computation,” Terry Knight and George Stiny make a distinction between different types of computational processes. The computational aspects discussed in the article are that of representation and process: the way that objects in computation are described and the rules that are used to carry out the design process (Knight and Stiny, 2001). Representation is divided into two types: verbal and visual. Verbal representation uses calculations with symbols, numbers or fixed set of primitives that define an object and its possible transformations, while visual representation uses shapes and narratives designations that promote vagueness. In a similar way the above process is divided into two types depending on whether or not the rules used are known and understandable enough to explain what is happening.

Rule-based design methods that use the second kind of representation, that of using shapes as units of their vocabulary and an understandable set of rules to describe their relationships, could provide answers to the description problem of design activity. Shape calculation could be a beneficial way to describe designers’ activities. Finally, as the aim of this thesis is to understand the way designers organize shapes in their designs and identify the rules that they are using, a shape calculation method, that of shape grammar, will be used to analyze designers activity. In the following section I will describe the basic characteristics of this method.

## **2.4 Shape Grammars**

When someone uses the term “algorithm” and “algorithmic design,” she usually refers to a computational system of text, symbols and the equations between them. Design, however, mostly relates to points, lines and their possible arrangements to planes and solid geometries. Shape grammars were invented in 1972 by George Stiny and James Gips (Stiny, 1994) in order to combine these two seemingly contradictory

fields, mathematics and design; shape grammars propose a way of calculating with shapes. Shape grammars were *“one of the earliest algorithmic systems for creating and understanding designs directly through computations with shapes, rather than indirectly through computations with text or symbols”* (Knight, 2000 update). This language was invented so as to carry out spatial computations visually. It is a system that uses production rules so as to generate shapes and designs. A basic principal for the creation of these rules is that they are based on what we see. Shape grammars, thus, introduces a new way of approaching design through calculation and shows new paths of experimentation.

A shape grammar consists of rules and an initial shape (Stiny, 1985). The rules apply to the initial shape and to shapes produced by previous rule applications to generate design. Thus, the basic components of a grammar are shapes of any kind, one dimensional, two-dimensional or three-dimensional. The arrangement of these shapes in space defines the spatial relations, which lead to the creation of rules that form the shape grammar. There are four possible spatial transformations that can occur between shapes: translation, rotation, reflection and scale. This process results in different designs.



There are two types of shape grammars: standard grammars and parametric grammars (Figure 3). The case of standard grammars refers to fixed spatial relationships; each rule is defined explicitly by a pair of shapes separated by an arrow. The shape on the left side of the arrow determines the part of a shape to which the rule may apply, whereas the shape on the right side of the arrow describes the shape that results after the application of the rule. On the other hand, parametric grammars allow a variation of spatial relations; instead of a specific shape rule, a wider rule in the form of schemata defines the shape relation implicitly. In this case characteristics of the shapes, such as line-length or angles between lines, can vary. The rules that control this variation result from values that are assigned to those variables.

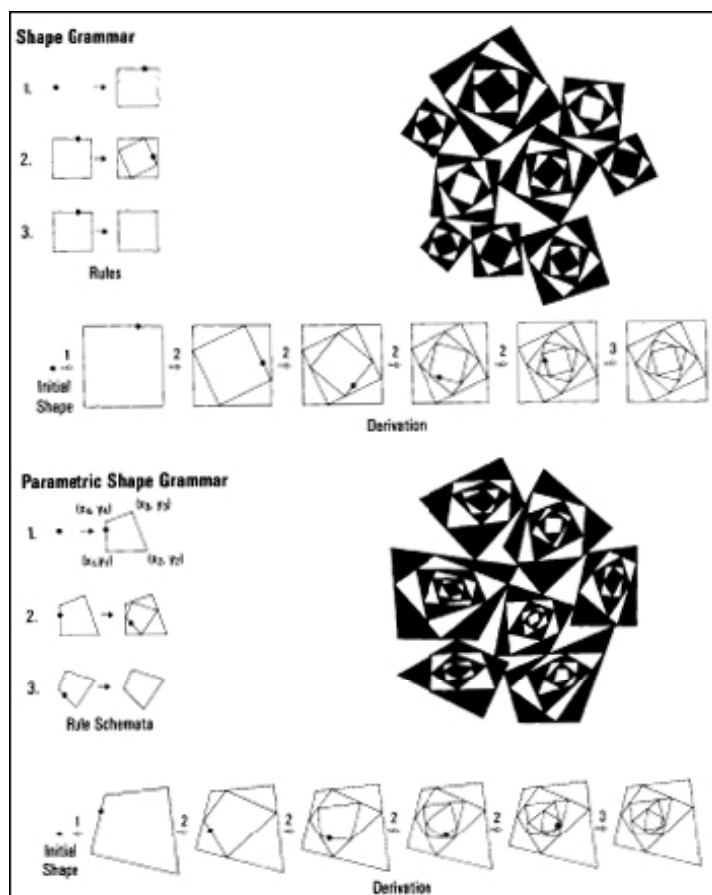


Figure 3: Example of Standard and Parametric grammars

## **Shape grammars in Design**

The use of shape grammar in design addresses two architectural design problems (Stiny, 1985). Firstly, shape grammars help designers to analyze and understand an existing style. Secondly, they allow the development of an original design composition, a process which involves the definition of new languages of design from scratch.

In the case of style definition, shape grammars help the designer to construct the rules that will generate the existing designs and at the same time provide a field for creating new ones in the same style. Therefore, a designer first analyzes an existing shape, and then codifies this information into a set of rules – a grammar – that can be used to generate more shapes in the same general pattern.

The second problem that shape grammars deal with is that of original design composition. In this process, the designer defines a vocabulary of shapes and a set of spatial relations between these shapes. Having as a starting point these spatial relations, the designer will try to generate designs by combining them in different ways.

Shape grammars propose a combination technique, which defines a vocabulary of shapes with which the designer wants to experiment. The definition of certain relations in terms of rules between them may lead the designer to new compositional paths. Furthermore, if the designer carries out this computational technique in a computer with the help of the advanced designing programs, then he/she could quickly produce different results. Additionally, the computer can produce other complex motifs in new arrangements in space, motifs and arrangements that the human mind might not think of.

In both cases, shape grammars use a clearly defined set of rules to address design analysis and synthesis. The repetition, however, of a specific set of rules and shapes may lead to a monotonous composition. Architects claim that the strict rules of shape grammars leave no space for ambiguity, which is an important characteristic of design, and thus may easily lead to meaningless repetition. It is this characteristic of

shape grammars that serves as a main point of critique against them. Monotony, though, can be avoided if something unexpected happens – if, for example a new shape emerges.

In shape grammars an “emergent shape is a shape that is not predefined in a grammar, but one that arises or is formed, from the shapes generated by rules applications” (Knight, 2003). Furthermore, emergence involves not only the creation of an unexpected shape but also the appearance of parts of shapes in a computation process. That means that a shape is not perceived as a definite unit, but as a sum of many indefinite parts. For example, someone can see different shapes in the first shape in figure 4: a square, four lines, for L shapes. According to Knight, this kind of emergence goes along with ambiguity where “shapes can be constructed from certain parts and then decomposed into their parts that become the basis for continuing the computation” (Knight, 2003).



*Figure 4: Different perceptions of the same form*

The present thesis uses a shape grammar formalism to address design composition from scratch at the early phase of design. I explore how this particular computational method could describe designers actions while working towards a design solution. In that process I also investigate the role of emergence; when and how emergence occurs in design process and in what ways designers incorporate it in their design actions and design solutions.

### 3. Dissecting Design

The undefined character of the design process, as described in the previous sections, has proved problematic, especially today, when the introduction of new design tools in the field of architecture is challenging the traditional ways of designing. While traditional tools and processes, at the early phase of design, are based on the designer's intuition and support the use of implicit actions, the new computational tools are based on very explicit processes and rules. I believe that in order to bridge the two, we need to understand if and how the designer employs rules and computational processes during the creative phase, and if that is the case, of what kind they are. Different design tools impose different design processes, so if we want to use, improve, or even invent tools to effectively address the design process, then we need to have a better insight on how designers generate their actions during the design process.

As a first step in this research several questions are addressed. These questions are organized in three categories; formulation of the design problem, organization of the designer's actions, and actualization of the design activity. The last category refers to the way that the designer proceeds in the construction of the actual design. More specifically, the questions addressed are:

*How do designers formulate the information contained within a design problem?*

*How do designers organize their actions towards a design solution?*

*How do designers move between different solutions?*

In all of the above design processes I am interested in both exploring the role or rule and investigating how a computational process could encapsulate designers' activity. A fourth question is therefore formed:

*Do designers use rules or patterns of rules in the above processes? And if so, what kind of rules or patterns of rules do they use?*

### **3.1 The experiment**

#### **3.1.1 The participants**

In order to conduct the above inquiry, I decided to set up a design experiment with a group of professional architects. All of them participate in the research group Affinities and work in the architectural firm Bergmeyer, in Boston.

Bergmeyer is a 75-person architecture and interior design firm specializing in academic buildings, workplace, retail, and food service design, and commercial and residential developments.

Affinities is a curriculum of events at Bergmeyer which promotes and cultivates a design-centered culture. This curriculum augments design operations by standing outside usual business and market-associated activities. To obtain the desired educational benefits, these events occur without many of the normal influences of a typical project. This curriculum is called "Affinities" to suggest several meanings-the connections that occur, sometimes unexpectedly, when disparate things are considered simultaneously, the hidden relationships discovered in a careful examination of complicated causal relationships, and the bonds between people sharing a common task.

Twelve architects volunteered to participate in the experiment. They are:

- Robin Abraham, practicing architecture the past five years (Architect A).
- Dan Broggi, practicing architecture the past twenty-six years (Architect B).
- David Cockreham, practicing architecture the past three years (Architect C).
- Michael Davis, practicing architecture the past twenty-six years (Architect D).
- Doug Douts, practicing architecture the past twenty-seven years (Architect E).
- Darryl Fillipi, practicing architecture the past twenty-one years

(Architect F).

- Michael Kyes, practicing architecture the past eighteen years (Architect K).
- Lewis Muhlfelder, practicing architecture the past twenty-seven years (Architect M).
- Nkechi Okwara, practicing architecture the past seven years (Architect O).
- Maria Panagopoulou, practicing architecture the past twelve years (Architect P).
- Derek Rubinoff, practicing architecture the past fourteen years (Architect R).
- Michel Stadelman, is in the second year of her graduate studies in architecture (Architect S).

### 3.1.2 The Design Problems

*“We're seeing constraints as opportunities. It's not like we're getting around the constraints. We're saying, 'The project's just the constraints.' If we can solve the constraints, that's where the form will come, that's where the beauty will come, that's where the logic will come. And more likely than not, you can get it built, you can get it financed, you can get it on budget.”*

*Rem Koolhaas, interview with Andrew Blum*

Many architects have mentioned the importance of constraints for the design process. Rem Koolhaas goes even further by stating that “the project is just the constraints” since the design solution derives from their manipulation.

Every design problem is characterized by a certain level of constraints. This level usually varies: there are design problems that are over-constrained, other that are less-constrained and others that are located in-between the two situations. For some designers constraints constitute a challenge that stimulates them and enhances their design processes. Other feel restricted in constrained problems and prefer those that are less constrained, where they feel more free to create an object. However, the fact that the design problems of the second category are less-constrained does not signify that constraints are not needed or not applied during the design processes. The difference is that, while in the first case the designer responds to the constraints imposed by the problem, in the second case the reverse situation occurs: the designer imposes his/her own constraints on the problem and is then free to follow, change, and abandon them at his/her desire.

In this thesis the observation on the importance of the constraints for the design process was further enhanced by the film “The Five Obstructions,” directed by Lars Von Trier in 2003 (Figure 5). The film is a documentary, where Lars Von Trier has created a challenge for his friend and mentor, Jørgen Leth, another filmmaker. Von Trier's favorite film is

Leth's "The Perfect Human" (1967).

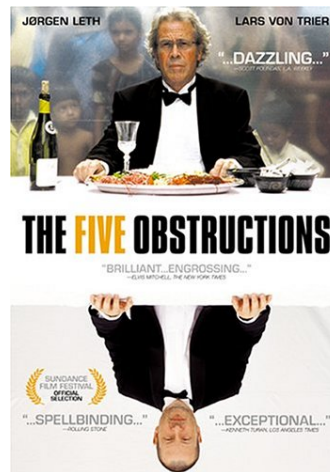


Figure 5: "The Five Obstructions"

"The Five Obstructions" describes Leth's task of remaking "The Perfect Human" five times, each time with a different "obstruction" (obstacle or constraint) given by Von Trier. Each time Leth created a set of rules to address the new situation. As a result five different films were generated.

Acknowledging the importance of constraints for the design process, I argue that designers form sets of rules around constraints so as to address the design problem and proceed towards the design solution. So as to understand if and how these sets of rules appear, to what they relate, and to trace similarities and differences among them, I formed my experiment around different levels of constraints. More specifically, I created two versions of the same housing project (Figure 6). In both cases the client, a four-member family, and the size of the site, 16.5' x 100', remained the same. The two design problems differ from one another in terms of levels of constraints – in particular, regarding site location, program specification, and building code. The first was located in Chicago, the second in San Diego. The building program was specific in the first case and free in the second one, and, lastly, there was a two-story limitation on the first problem and no height restriction on the second. My initial hypothesis was that, in the comparison of the two



solutions, I would be able to extract the rules organizing the processes the designers employed while working towards the design solution.

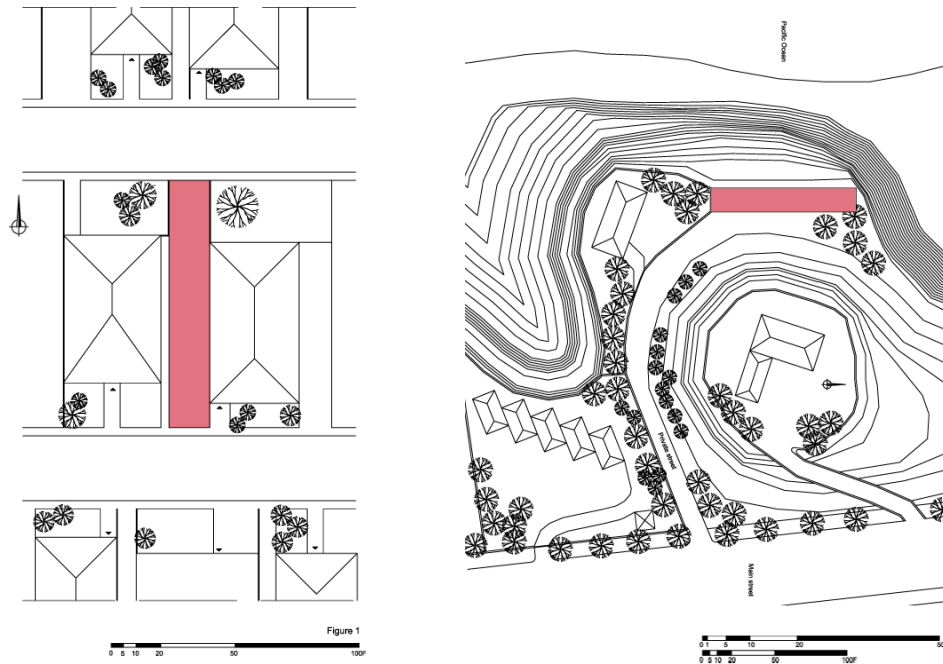


Figure 6: On the left: Design Problem\_01. On the right: Design Problem\_02

### 3.1.3 The Process

The method used in the experiment was a protocol analysis of reports of subject's design thoughts. The think-aloud verbal reports method (Simon and Ericsson, 1993), which is most common in analyzing subjects' cognitive processes was not employed, because as previous work suggested (Suwa and Tversky, 1997) thinking out loud may influence a designer's actions.

The experiment consisted of three tasks: two design tasks and one reporting task. In each design task the participants were asked to solve a design problem in a one-hour session. They were provided with a simple diagram presenting the site in which they were asked to locate a family house. Participants were free to use whatever representational medium they wanted as a tool for design. They were not asked to

describe their moves and actions while they were designing, nor were they interrupted during that time. In order to keep track of the process that each architect followed towards solving the design problems, a video camera was used to record the architects' design decisions.

The two design tasks happened sequentially in over a two-day period. One week after the design tasks were completed, the reporting task followed. I met with each participant and together we reviewed the process he/she followed with the aid of the videotapes. More specifically, while watching the videotapes, I asked participants to describe the moves and the decisions they took during the design process. They were asked to remember and report with as much detail as possible what they were thinking as they were designing. During the interview I asked them specific questions related to several categories that coincided with the initial questions of this thesis, as well as to respond to issues of design constraints and design tools used during the design process. These categories were: formulation of the information contained in the design problem and organization of their actions towards the solution, creation of the actual design, comparison of the two design problems and representational medium. More specifically, the questions were:

**1\_ Formulation of the design idea and organization of design actions**

1\_ Did you have an idea at the beginning?

2\_ How did you proceed with your idea?

Describe the steps that you followed in order to achieve the first solution.

3\_ Did you repeat an action?

4\_ Did you develop an action regularly?

5\_ Did you reuse previous ideas or elements?

## **2\_Creation of the actual design**

Whenever there was an alteration in the design solution I would ask the architect to describe to me what led him/her to change the previous solution.

1\_Why did you alter the solution?

2\_Did you see something in the design?

## **3\_Comparison of the two design problems**

1\_Do you have a specific strategy (pattern of actions) that you follow while designing?

2\_ How do you feel about constraints in design?

Do they help you?

Do you prefer problems that are less constrained?

3\_ Compare the two problems in terms of constraints.

Did the existence of constraints facilitate/hinder your exploration?

How?

4\_Did the first exercise affect how you approached the second?

## **4\_Representational medium**

1\_Which is the representational medium that you normally use?

2\_How did the representational medium affect your actions?

Did it limit the exploration of your ideas?

Did it enhance the exploration of your ideas?

The whole session was video taped.

### **3.2 Analysis of the experiment**

The completion of the three tasks was followed by the analysis of the protocol, which happened in the following steps. First, the verbal protocol recorded from the design sessions was transcribed. The next step was the analysis of the designs based on the visual representation of the drawings and their verbal descriptions. Every design solution was divided into three segments: 1. the formulation of the design problem and the organization of design actions 2. the construction of responsive mechanisms, and 3. the final solution. Initially, the first segmentation consisted of two distinct parts: formulation of the problem and organization of design actions. The analysis of the design processes, however, revealed a difficulty in the division between the two, because, in most cases, they happened simultaneously. As a result, the two segments were combined into one. Lastly, in the final step, the two design solutions that each participant produced in response to the two design problems were compared according to the above three segmentation categories.

The analysis of the design solutions led to the formulation of several groups of design activities, depending on the different ways that the architects responded to the design problems and the various design actions that followed this response – from the diagrammatic form to the completion of the final solution. While the elements involved in the above processes continuously interact and inform one another during the whole period of the design process, the focus of the analysis was to discern, if possible, a dominant element that structured the process towards the design solution. In the next section, I describe the three groups of design processes identified in the activities of the twelve architects that participated in the experiment.

### **3.2.1 Groups of design activities**

The analysis of the twenty-four design processes that the architects followed in the experiment formed two basic groups of actions: processes based on information provided by the design problem and processes based on personal information imposed by the architect. These groups correspond to the categorization of the design problem, based on constraints, made by Simon in 1970 and described by Peter Rowe in the book *Design Thinking* (Rowe, 1991). In this categorization, design problems are divided into those that include “problem-oriented constraints” and those that involve constraints that are autonomous and independent and are imposed by the designer so as to organize the information contained in the design problem. Taking into consideration the above categorization, I named the two groups as follows: processes based on problem-derived constraints and processes based on personal-derived constraints.

#### **Processes based on problem-derived constraints.**

The architect formulates the information contained in the design problem and organizes his/her actions towards the solution on the basis of the information and the constraints included in the design problem. In other words, the architect finds the necessary and sufficient information for taking action towards the design solution within the boundaries of the design problem. This information, in most cases, describes programmatic elements and site conditions. In the analysis of the present experiment ‘s results, these two types of information – program and site – appeared as distinct, and therefore they were organized into two different design processes subgroups. This division does not mean that the subgroups are independent of one another. On the contrary, they are in constant relationship and inform each other continuously. However, the architect’s primary concern usually focuses on one of the two.

### ***Site-derived constraints***

The architect first identifies primarily the peculiar characteristics of the site and starts organizing his/her actions based on the information extracted from it. By tracing the lines of the general plan, he/she examines adjacencies, solar orientation, accesses to the house, neighboring conditions (building heights, views etc.), set-backs etc. At a second level, he accommodates, randomly in the site or in an early footprint, the programmatic requirements of the house.

### ***Program-derived constraints***

In this case, the first move of the architect is to understand the programmatic requirements of the design problem. Usually the calculation of the average area that each room will occupy describes the architect's early actions. Through this process the architect forms a general idea of the area that the building will engage and then structures his/her actions accordingly. Early on, a general footprint is selected to accommodate the required functions.

### ***Processes based on personal-derived constraints***

The architect formulates the information contained in the design problem and organizes his/her actions towards the solution by introducing information from somewhere else, rather than direct considering the design problem's program and site conditions. Again, the distinction between the two aspects is not definite; even though the architect imposes her own constraints at the end she addresses a specific design problem with specific programmatic requirements and site conditions. The difference between the two groups, however, lies in the selection of the fundamental constraint that will organize the design process towards the design solution. In this group these constraints are usually found outside the boundaries of the information contained in the design problem. According to protocol analysis and case studies (Cross, 2006), architects develop a "fixation" to these constraints imposed at the early

design phase; designers insist on them as long as possible and build their design solutions around them. These constraints appear in different forms. The analysis of the present experiment revealed the following types: typology, precedent images, literal analogies (grid), personal principles and desires (for example “I wanted to make a tower building”).

The following table (Figure 7) illustrates the categorization of the architects’ design processes in the three groups described above.

Problem-derived constraints		Personally-derived constraints
Site	Program	
Architect D	Architect R	Architect P
Architect M	Architect C	Architect E
Architect K	Architect A_01	Architect F_01
Architect F_02	Architect S_01	Architect B
	Architect O	Architect A_02
		Architect S_02

Figure 7: Table of groups of design activity

An interesting conclusion that can be extracted is that in the group of the processes based on program-derived constraints are mostly novice architects, with a working experience ranging between a few months and five years. On contrast, the most experienced architects are found in the group of personal-derived constraints. It seems that novice architects, who have not yet developed a personal design process to tackle design problems, hang on to the programmatic requirements, so as to proceed towards the solution. On the other hand, experienced architects, who throughout their design practice have created a method to address design problems, occasion to employ their design method.

In order to examine how a computational method can describe the design processes that architects employ at the early design phase, an example of each category is selected and illustrated with the aid of a

shape grammar formalism. Each example will be developed in four sections:

1\_ Presentation of the first design experiment based on the protocol analysis segmentation;

2\_ Presentation of the second design experiment based on the protocol analysis segmentation;

3\_ Presentation of the general rule schemas used in the design process, from organization of the design problem to the creation of the final solution;

4\_ Illustration of the design process and solution through the model language of shape calculation.



## 4. From Rule Schemas to specific rule application

### 4.1 Process based on site-derived constraints

From the group of the design processes based on site-derived constraints I chose to analyze the process of architect D. The architect proceeded in a similar way in both design situations. The next to figures (8, 9) illustrate all the drawing that the architect produced while he was working towards the design solution.

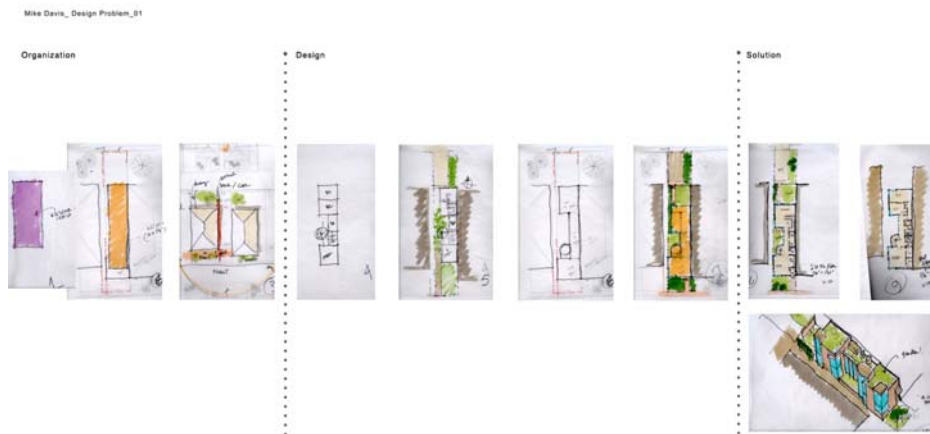


Figure 8: Architect D: Design Problem\_01

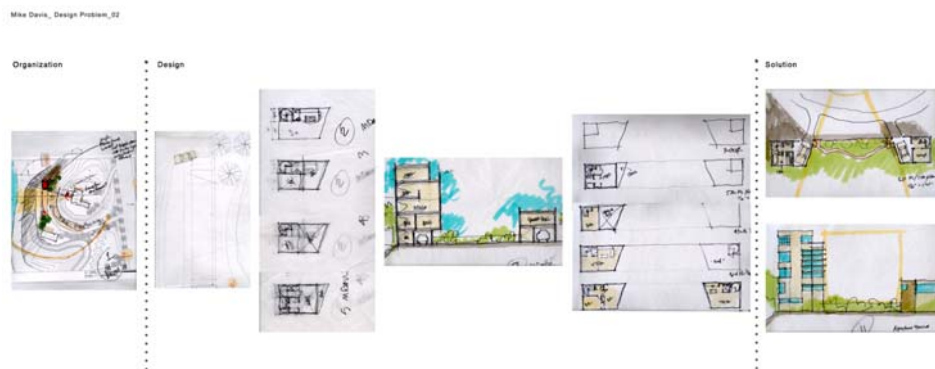


Figure 9: Architect D: Design Problem\_02

#### 4.1.1 Design Problem\_01

##### ***Formulation of the problem and organization of design actions***

The first action of architect A was to divide the total square footage of the programmatic requirements into two equal parts of 625 sf. He then continued by examining the possible shapes of these parts; both x and y dimensions varied. The house's x dimension was either the same as the x dimension of the site or was the 3/4 of the site's x dimension. This reduction provided sufficient space for an exterior sidewalk. The y dimension varied, but was always determined and limited between the boundaries of the neighboring buildings. As a result, two solutions were produced: in the first one the x dimension of the house was identical with that of the site and the house was aligned with the southern (lower) border of the neighboring building. In the second solution a corridor was left on the west side and the house was aligned with the northern boundary of the neighboring building (Figure 10).



Figure 10: Architect D, Design Problem 01: Organization

On the next tracing paper the architect started tracing the lines of the general site plan: the neighboring buildings, the set-backs, the solar orientation. In this sketch he defined the back and front sides of the house and then placed the accesses to it: one on the back and the second one in the middle of the site, coming from the front. His next

move was to place the house uses; kitchen at the back, living room at the front and, accordingly on the above floor, two bedrooms at the back and master bedroom at the front. His final decision on this sketch was to place the parking space at the back.

The completion of this sketch helped the designer to form a decision concerning the way he was going to proceed with the design solution. His response (Figure 11) to the site constraints was to create a house with a garden somewhere in the middle.

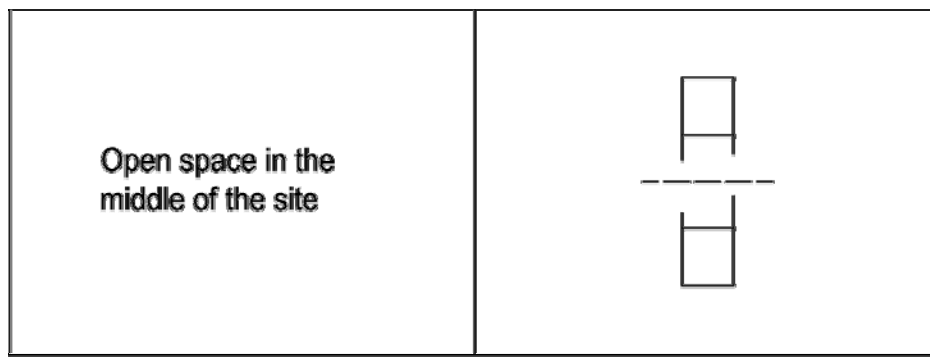


Figure 11: Architect D, Design Problem 01: Response

### ***Actual design***

In the next sketch he proceeded with a diagrammatic arrangement of spaces on the footprint of the second solution, the one with the pathway. The general orthogonal footprint of the house was divided into two parts, which were to accommodate the basic functions of the house: one (part A) was located at the front of the site and the second (part B) at the back. The two parts were connected with a third shape (part C) which had to fit the size of the other two parts (in the x dimension) and hosted the house's internal circulation as well as the secondary functions. The architect was using a rational way of dividing space, by always selecting a specific proportion to work with. The length of the house was not yet determined. The architect's last action in this sketch, which formed the final version of the house schema, was to locate a circular stair (part D) in the north west corner of the front part.

Moving to the next sketch, the architect started dimensioning the house's spaces in order to determine the final shape of the house. He resized the house; part A and B were aligned with the east neighboring house. Consequently, part C became longer in order to cover the distance between the other two parts. The x dimension of part A changed and became the same as the x dimension of the site. Parts B and D remained unaltered. Another change in this sketch was the relocation of the garden entrance from the front to the back (Figure 12).

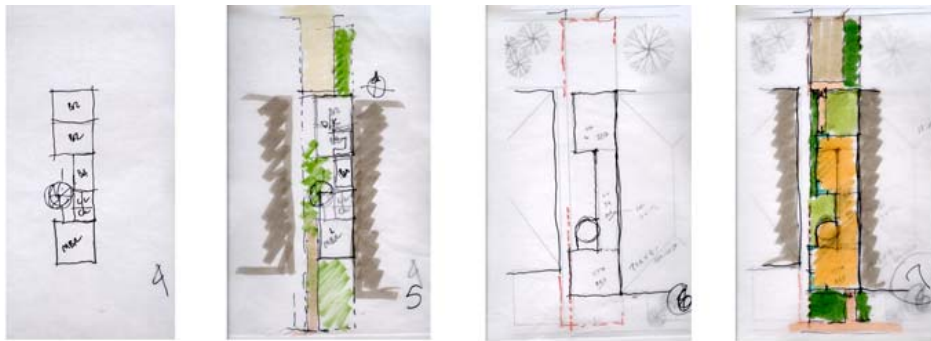


Figure 12: Architect D, Design Problem 01: Design

In the following sketch the architect continued to resize the house's dimensions. Part C became shorter, because the previous solution exceeded the required square footage. Part D was also changed and became tangent to part A. At this point the designer identified as an important element of his design the four corners of the building, which he then highlighted by placing there corner windows. After this action he named his house "the corner house."

In the design of his final solution (Figure 13) the last resizing action occurred; part B became the same as part A. The architect then proceeded by refining both floors of his design solution. In his last sketch he designed an axonometric so as to display different aspects of his solution as shown on the facades of the house.

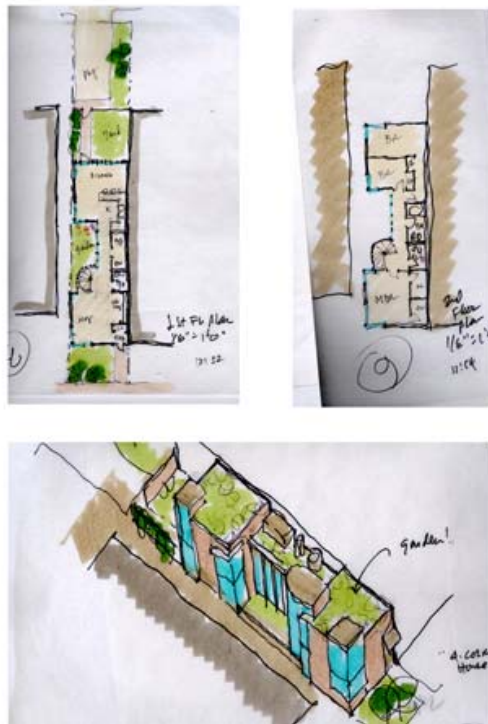


Figure 13: Architect D, Design Problem 01: Solution

### ***Rules in the Design Process***

The architect proceeded in the designing by first identifying the site's special conditions and constraints in order to find the basic guidelines to develop his design solution. This process resulted in the formation of his response to the design problem, the decision to create a house with an open space in the middle.

The actualization of this design decision on paper was characterized by the use of a symmetry rule. The shape of the house was abstractly divided into two parts and whatever was happening on the one side was affecting the other side, either in terms of distinguishing or mimicking. The architect was using bilateral symmetry.

Another rule employed in the design was that of connection between two parts. The architect created two basic spaces, which he decided to connect with a smaller, secondary third space.

An interesting action of the architect was to place the circulation in a corner of the house. The stairs took the shape of a circle, just from the beginning of the design process, and were located at the north west side of the house.

Lastly, the architect's actions to rationally divide the spaces of the house constitutes another rule applied in the design solution. The architect's division moves were always guided by a proportional relationship: the connection shape is divided in two equal parts, the initial part of the house hosting the two bedrooms is again divided in two, while the room corridor constitutes one-fifth of the bedroom's dimension.

Overall, the architect at the beginning of the design activity forms a general framework based on the manipulation of certain site constraints. These frameworks involve some general laws that provide the architect with a method of approaching the design problem. As the architect proceeds with the solution, these general laws are gradually made more specific and refined explicit design actions.

#### **4.1.2 Design Problem\_02**

##### ***Formulation of the problem and organization of design actions***

In the second design problem the architect started by immediately tracing the lines of the general site plan. Again, he was interested in the solar orientation, the neighboring buildings, the possible accesses to the house, but also in the views to the sea and the site's slopes. First the information extracted from the site did not provide him with a specific guideline that he could use to start working with. Since he was stuck, he then decided to create a sketch of a section in order to examine the slopes of the site in more detail. That sketch helped him realize that the neighbors' views constituted an important characteristic of the site he should take into consideration: he decided their ocean shouldn't be blocked. This thought formed his response to the problem's constraints and he opted to locate two structures at the ends of the site. While still

drawing on the same sheet, the architect went back to the plan and started developing his idea further (Figure 14).



Figure 14: Architect D, Design Problem 02: Organization

First he placed an axis of symmetry on the site and then he continued by designing two symmetrical lines at an angle to indicate the neighbors' views. He knew by that time that he wanted the house located at the two edges of the site. These two last lines gave him two quadrilateral shapes the edges of the site. The architect liked this result and so he decided to incorporate it in his solution; he used the north quadrilateral to put the house, and the South one to locate the garage.

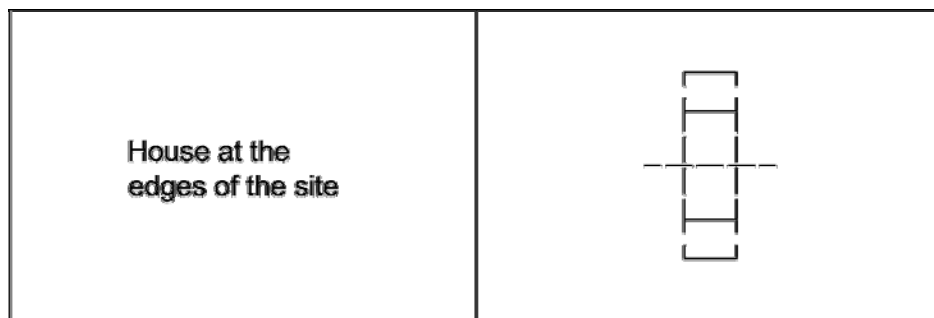


Figure 15: Architect D, Design Problem 02: Response  
**Actual Design**

The architect proceeded in a new tracing paper. He changed scale – moved to a larger one – and created several plan variations. In every plan sketch the stairs were placed in the same location, in a 90 degree

corner. For dividing space into smaller rooms the architect followed a rational system of proportions of halves or thirds. The quadrilateral shape of the house did not affect these divisions, because the architect had extracted a rectangular shape out of it and was proceeding with that. The remaining triangle shape used either as a deck or as a room expansion (Figure 16).



Figure 16: Architect D, Design Problem 02: Design

After having finished with the plans the architect proceeded in section. From the first sketch until this point the architect had taken a decision to create a guest house above the garage space.

The architect used the last sketches (Figure 17) to illustrate more accurately his idea. He designed the final plans of each floor, then a west elevation and finally the first floor plan in the general landscape.



Figure 17: Architect D, Design Problem 02: Solution

### **Rules in the Design Process**

In the second design problem the architect, once more, proceeded by first identifying the site's special conditions and constraints in order to find a similar guideline to help him develop his design solution. This



process resulted in the formation of his response to the design problem described by the design decision of creating a house at the edges of the site.

Further exploration of the above design idea resulted in an emergent shape; that of quadrilateral. The architect employed the identity rule (Stiny, 2006) that describes the situation where the architect recognizes a shape in the drawing that she could not see before, extracts it from the surroundings, incorporates it and proceeds with the solution – this rule will be further analyzed in a following section.

Even in this situation of emergence, the architect employed the rule of bilateral symmetry, as in the previous design problem. The house was divided into two parts and whatever was happening on the one side was affecting the other side, either in terms of distinguishing or mimicking. The difference in this case was that the symmetry was followed only in plan and not in elevation or in section.

Another rule employed in the design, similar with one employed in the previous solution, was that of connection between two parts. In this case the architect designed the connection only in the last drawing using a curvy shape. He said “at the beginning I thought of connecting them (the two houses) with a straight stripe kind of way, but then I changed my mind and I followed the landscape.”

A different rule, used in the same way in both design solutions, describes the location of the circulation, which is always placed in a corner of the house. The architect was treating the stairs not as a structural element of the house, but rather as something that he wanted to hide. His wish was for the stairs to occupy the minimum possible space, “I placed the stairs there for efficiency reasons.”

Finally, the architect's actions of rationally dividing the spaces of the house describes another rule applied in the design solution, same as before. The architect's division actions were always guided by a proportional relationship of halves and thirds.

### **4.1.3 Rule Schemas**

The protocol analysis, presented in the previous sections, revealed that the architect proceeded in a similar way in both design problems. In the two cases the architect developed his response to the design problem by forming his actions around constraints deriving from the special site conditions. The comparison between the design activities of the architect, in both cases, revealed that some of these actions were similar in the two processes. These actions can be described by rules, which for the present thesis comply with the language of a shape grammar formalism. At the early phase of design, the rules that the architect used were not fixed or explicit, but were rather expressing some general intentions about spatial relationships. They could apply to any spatial configuration and for that reason they do not require a specific vocabulary of shapes. Therefore, for this stage of design, rule schemas are proposed instead of specific rules and are expressed in the following table (Figure 18). These general rule schemas describe the architect's design process, as well as the final design solution.

Rule Schemas	
1. Place an axis into the site	
2. Use of Bilateral Symmetry	
3. Divide	
4. Dimensioning a schema	
5. Connect	


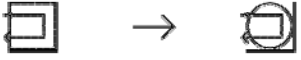


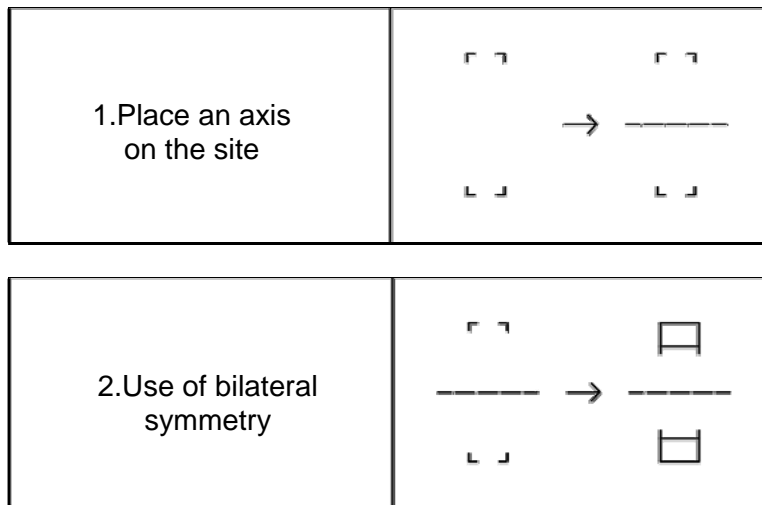
<p>6.Circulation</p>	
<p>7.Give circulation a shape</p>	
<p>8.Replace a shape</p>	
<p>9.Symmetry</p>	

Figure 18: Architect D, Rule Schemas

#### 4.1.4 Rule Schemas Descriptions

In the following section each rule schema will be described and analyzed separately.

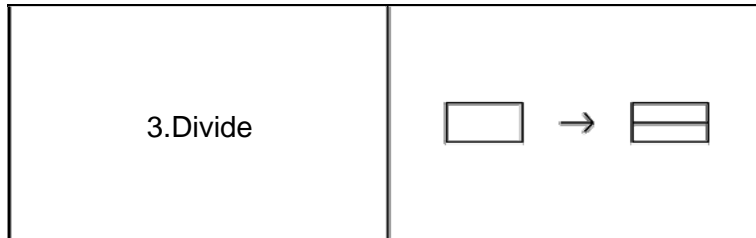
**Rule Schemas 1 and 2:** The first two rule schemas refer to the action of symmetrically designing space and more specifically to the application of bilateral symmetry. As William Mitchell states in his book *The Logic of Architecture* (Mitchell, 1989), bilateral symmetry is the kind of symmetry possessed by the human body. Claude Perrault described symmetry as “the relationship which parts on the left side have with those on the right, those high up with those low down, those in back with those in front” (Mitchell, 1989). Therefore, the symmetry operation can be described by a reflection across an axis.



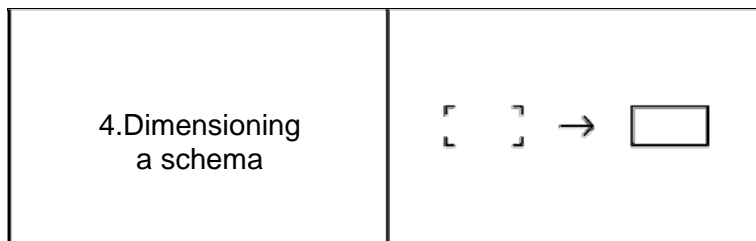
In order to accomplish the above operation, one should start by placing an axis of symmetry into the site, an action that is illustrated in the first rule schema.

The next step is the actual application of the rule of bilateral symmetry, as it is formalized in the second rule schema. This rule describes the characteristic of the architect's design compositions to evolve through isometric transformations (translations, rotations, reflections, and compositions of these).

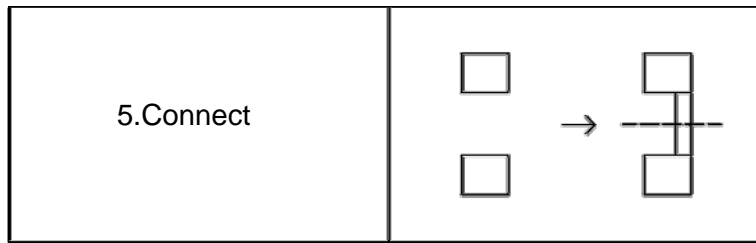
**Rule Schema 3:** This rule schema allows the division of an initial shape into several parts. The division should always occur in a ninety degree relationship with the initial shape's sides.



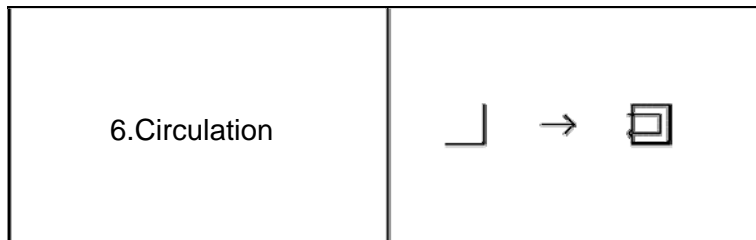
**Rule Schema 4:** The fourth rule schema describes the action of adjusting an initial diagrammatic schema so as to meet the exact programmatic requirements. An initial vague shape could be dimensioned and consequently transformed into different shapes until it is finalized to the one fulfilling both the architect's intentions and the program specifications.



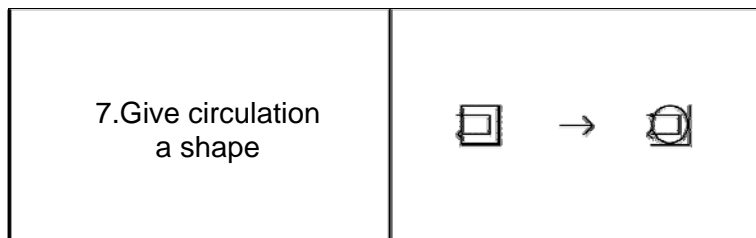
**Rule Schema 5:** The fifth rule schema permits the connection between two shapes through the use of a third shape. In the rule illustration two quadrilateral spaces are connected with a third quadrilateral shape. The quadrilateral shapes do not serve as the actual representation of the shape, but rather indicate a general shape configuration.



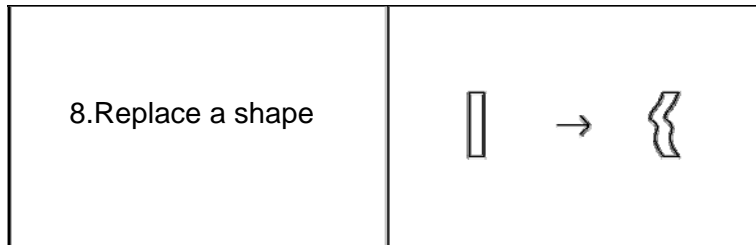
**Rule Schema 6:** This rule schema describes the location of the house circulation between the different floors in a corner of the house. Given a house corner, the rule illustrates the starting point of the circulation as well as the end point within the boundaries of the shape.



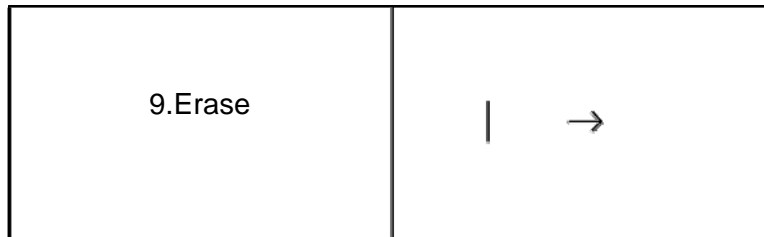
**Rule Schema 7:** The seventh rule schema provides a shape to the schematic representation of the circulation. The shape does not have a specific form and always depends on each design problem's special conditions. For example in the experiment's two design conditions the architect chose to work with a circular shape. In a different problem, however, he could proceed with a totally different shape (e.g. rectangular, square etc.).



**Rule Schema 8:** This rule schema allows the replacement of a shape with another one of different kind.



**Rule Schema 9:** The last rule schema permits the action of erase. During the design process the architect can select a line or several lines that he does not want and erase them.

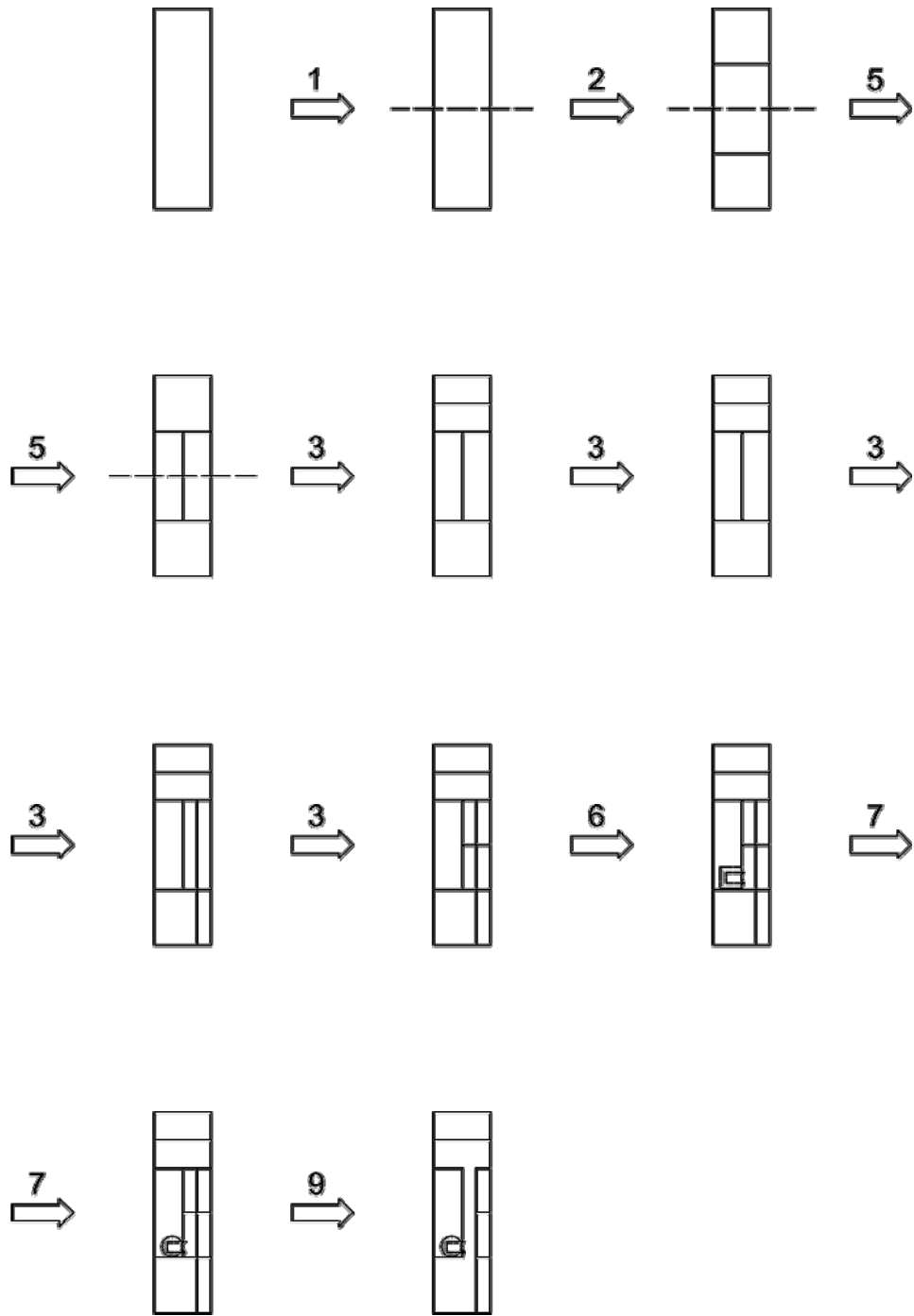


### ***Schematic Derivations***

The rule schemas described in the previous section are put into use in each design process. They serve as guidelines for the architect in order to create plan descriptions. In this section two examples, one for each design problem, will be presented illustrating how the spatial relationships described in the previous tables of rule schemas result in specific plan descriptions. The architect in every design step of each design solution was gradually transforming these general rule schemas to specific and explicit application of rules; a process that resulted in the final solution.

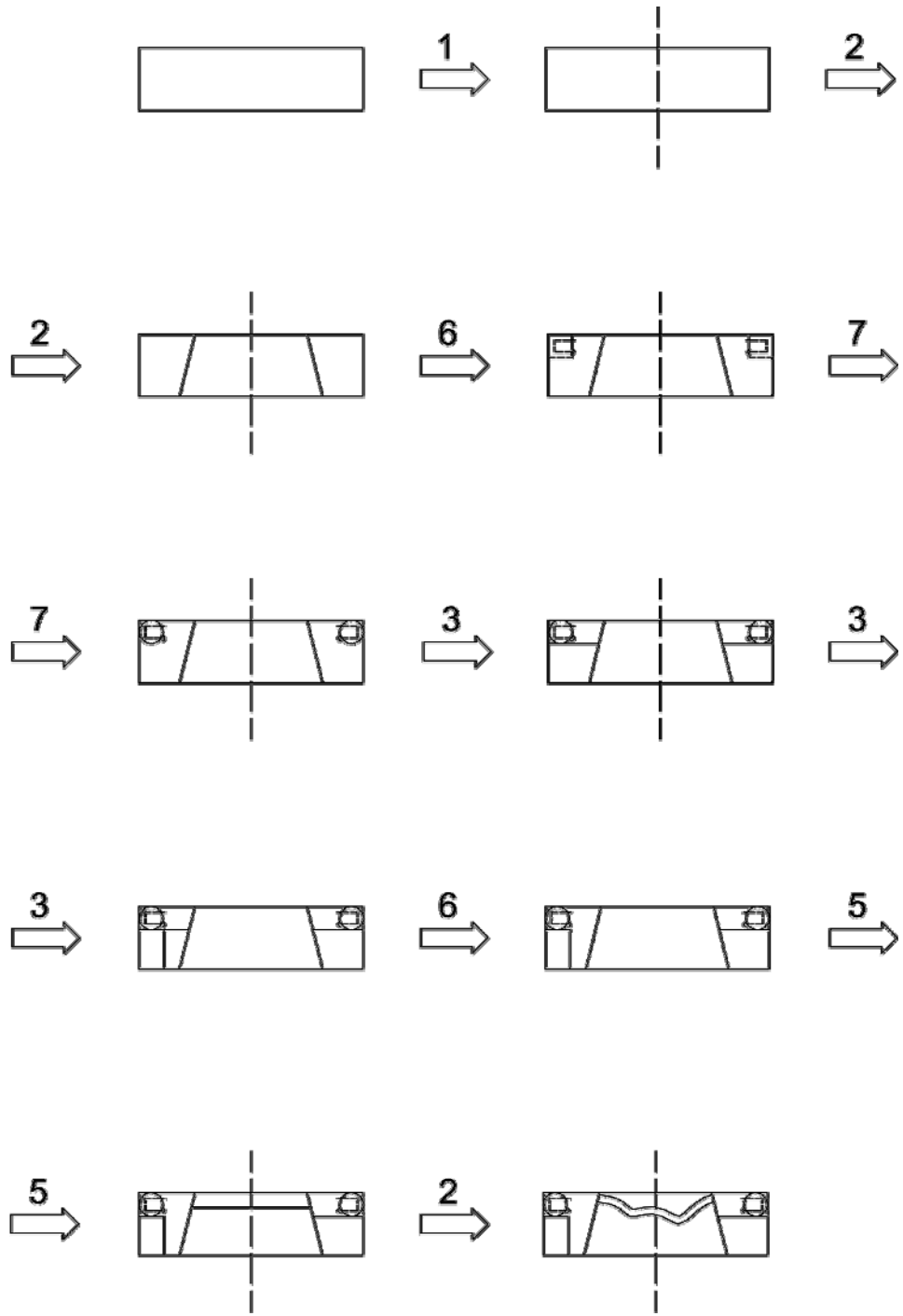


**Schematic derivation for the first design solution**





**Schematic derivation for the second design solution**





## 4.2 Process based on program-derived constraints

From the group of the design processes based on program-derived constraints I chose to analyze the process of architect R. The architect proceeded in a similar way in both design situations. The process he employed while working towards the design solution, however, was totally different from the one used by the previously analyzed architects. The next two figures (18, 19) illustrate the architects design process and the final outcome.

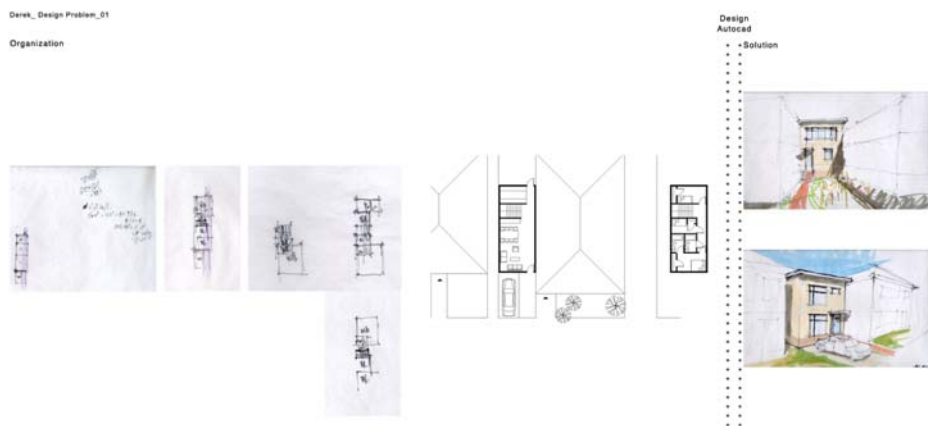


Figure 19: Architect R, Design Problem\_01

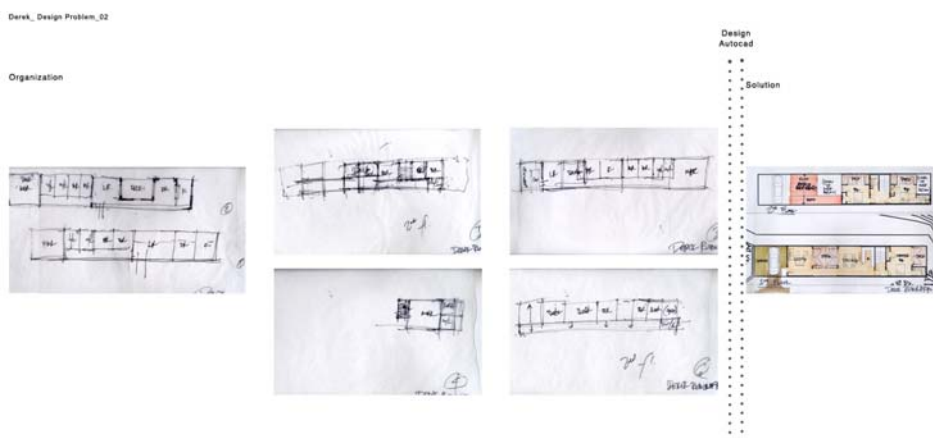


Figure 20: Architect R, Design Problem\_02

#### 4.2.1 Design Problem\_01

##### ***Formulation of the problem and organization of design actions***

The architect's first reaction to the design problem's information was to write down the programmatic requirements of the house. After having calculated the average area of each room in square footage, he proceeded by examining possible spatial arrangements. *"I cannot sketch a diagram in plan of how the space is going to layout overall without understanding about every box, even if these boxes become circles,"* the architect explained.

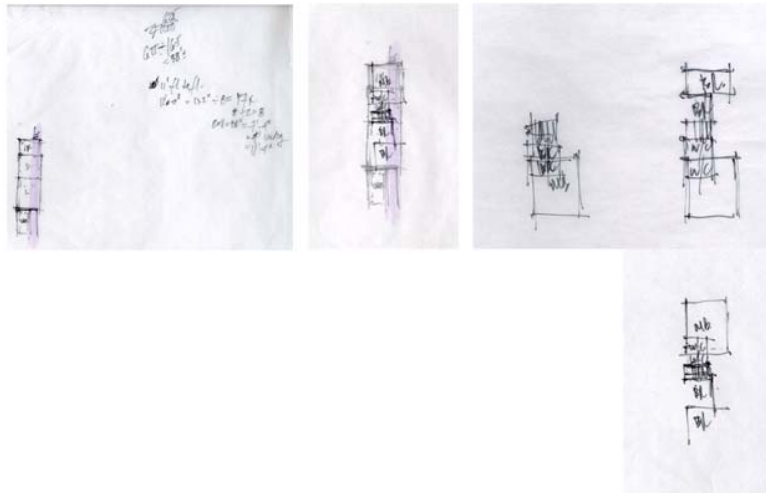


Figure 21: Architect R, Design Problem\_01: Organization

At this point he made the decision of creating a two-story building. He started by drawing the first floor. Considering the adjacent buildings, the architect started by placing and organizing the rooms into the site (Figure 21). His process was an additive one: beginning with the kitchen and then the dining and living room next to it. His last move on this sketch was to indicate circulation by using a color pen and drawing a thick line on the east side of the site. By this action he did not specify the exact size of the circulation corridor, but rather outlined a general area of its possible location.

In the next series of sketches the architect proceeded with the second floor's plan. Using the same additive method, he tried several different room arrangements. The circulation again was treated diagrammatically and the action of its general spatial location was coming after the specification of the room adjacencies.

In the first design problem the architect's guideline was the programmatic arrangement of space. The completion of his first sketches formed the response to the design problem constraints, which could be described by the statement, "create blocks of space and fit them in a selected footprint." The following table illustrates the general rule that describes this response (Figure 22).

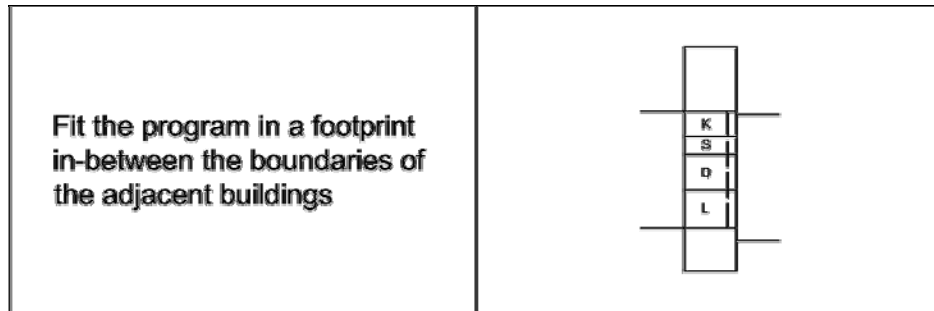


Figure 22: Architect R, Design Problem\_01: Response

### ***Actual Design***

In order to proceed with his exploration the architect changed the design medium and switched to the computer, where he used the software Autocad. There he continued with drafting actions, producing the final solution, which was not very different from his initial sketches, in plan.

In the last two sketches (Figure 23) the architect moved from plan to perspective. There with color pens, he first studied the openings of the house and then the house's relationship with the adjacent buildings.

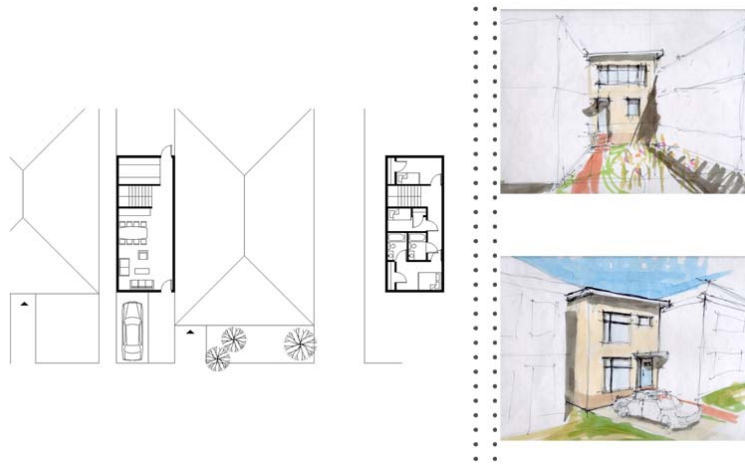


Figure 23: Architect R, Design Problem\_01: Solution

### ***Rules in the Design Process***

The basic concern of the architect was to translate the square footage of the house into general blocks of spaces. These blocks described each room of the house. The following action was the examination of possible combinations of these blocks. That could be contained within the house's footprint. This method described a progressive action from parts to a whole. The rule applied in the combination of the different blocks was that of addition; the architect started with a block of space and then was continuously adding other blocks next to it.

#### **4.2.2 Design Problem\_02**

##### ***Formulation of the problem and organization of design actions***

The architect proceeded in a similar way in the second design problem. In this case he was familiar with the programmatic requirements of the house and, so he did not need to write down or estimate the approximate square footage again. By having the blocks of space in mind the architect proceeded in the first series of sketches with the aim of creating a satisfying plan.

In his first sketch, the architect immediately continued by drawing the first floor plan. The first two sketches illustrate the architect's attempt



to fit all the programmatic requirements in one floor (Figure 24). This idea was soon abandoned. The solution of a two-story building seemed more appealing and so the architect proceeded with that.

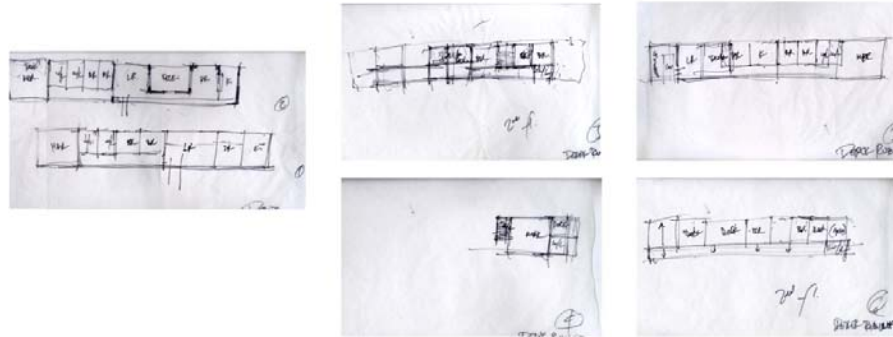


Figure 24: Architect R, Design Problem\_02: Organization

The completion of the first phase's sketch led the architect to the creation of his response to the design problem's constraints. As in the first solution, the architect's main consideration was around the house's programmatic requirements and the response could be summarized in the phrase, "fit the program into the site" (Figure 25).

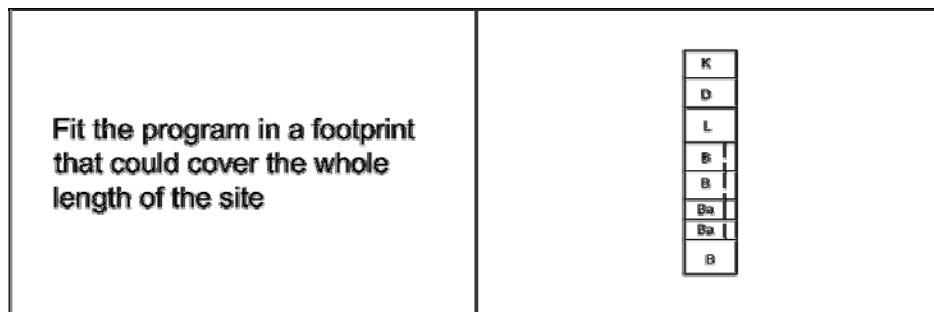


Figure 25: Architect R, Design Problem\_02: Response

### **Actual Design**

The completion of some diagrammatic sketches at the organization design phase was followed, as in the previous process, by a change in the design medium. The architect switched in the digital environment. He continued working on Autocad, where after several drafting actions he ended up with his final solution (Figure 26).



Figure 26: Architect R, Design Problem\_02: Solution

### **Rules in the Design Process**

The design process that the architect followed while working towards the design solution was similar to the one of the previous problem. The fact that the architect worked before on a similar problem provided him with the necessary knowledge to handle the problem, so that he used a different method. Instead of implementing an additive process he changed to a process of division; he drew an orthogonal shape indicating the house's footprint and then started dividing it so as to fit all the programmatic requirements.

In the second design problem the architect treated the house's circulation as in the first problem, that is as part of another space or as the leftover space.

#### **4.2.3 Rule Schemas**

The analysis of the architect's design activities, presented in the previous sections, revealed that he proceeded in a similar way in both design problems. The architect started by creating blocks of spaces and then tried to compose them into a whole. In his words, *"I do create block of*

*spaces like this with certain square footage and once I've got them defined I can start moving them around.*" The architect forms a general framework of actions around the design problem's programmatic constraints. The development of a shape computation translated these actions into rule schemas. In every design problem the general spatial relationships, captured in these rule schemas, become specific descriptions through the transformation of the rule schemas into explicit rules. In that process and after the initial response to the design problem, other operations, which can be also described with the form of rule schemas, are applied. These operations relate to personal preferences of the architect, for example the actions of addition and division. The combination of the two rule schemas help the architect to work towards the design solution.

The following table (Figure 27) illustrates the basic vocabulary of rooms that the architect used in both design problems: kitchen (K), living room (L), dining room (D), bedroom (B), bathroom (Ba) and stairs (S). The rectangular shape attached to each room definition describes the architect's general concept about the space (for example the kitchen is bigger than the bathroom) and does not necessarily reflect the actual shape.

Having in mind a vocabulary of shapes and their approximate sizes, the architect next tried several actions in different arrangements of them. The comparison between the design activities of the architect, in both design problems, revealed that some of these actions were similar in both processes. These actions are described in the form of rule schemas in the following table of Figure 28.

The next and last rule schemas' table (Figure 29) illustrates the possible room adjacencies. The possible combinations between the rooms do not happen randomly. On the contrary they follow specific rules. For example, the architect locates the kitchen next to the dining room, or the kitchen next to the stairs but he does not place it next to a bedroom.

Vocabulary of Shapes	
1.Kitchen	<b>K</b>
2.Living room	<b>L</b>
3.Dining room	<b>D</b>
4.Bedroom	<b>B</b>
5.Bathroom	<b>Ba</b>
6.Stairs	<b>S</b>

Figure 27: Architect R, Vocabulary of shapes

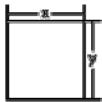
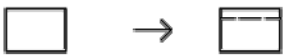
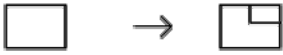

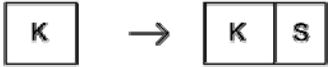


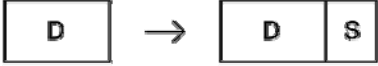
Rule Schemas	
1. Parametric Shape	
2. Add	$[l_2] \rightarrow [l_1   l_2]$
3. Divide	$[l] \rightarrow [l_1   l_2]$
4. Corridor	
5. Outdoor Space	
6. Erase	$  \rightarrow$

Figure 28: Architect R, Rule Schemas

Rule Schemas: Room Adjacencies	
i. Kitchen next to dining room	
ii. Kitchen next to stairs	
iii. Living room next to dining room	
iv. Living room next to bedroom	
v. Dining room next to stairs	


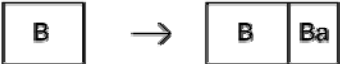
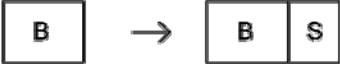

vi. Bedroom next to bedroom	
vii. Bathroom next to bedroom	
viii. Bathroom next to stairs	
ix. Bathroom next to bathroom	
x. Bathroom next to stairs	

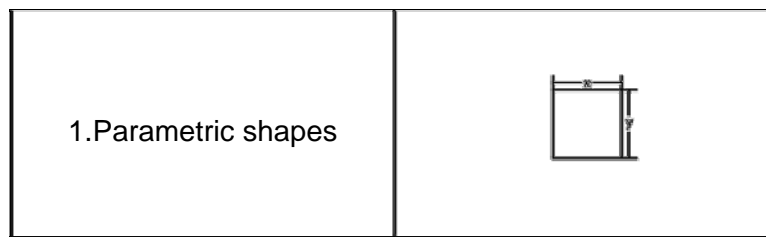
Figure 29: Architect R, Rule Schema: Room Adjacencies

#### 4.2.4 Rule Schemas Descriptions

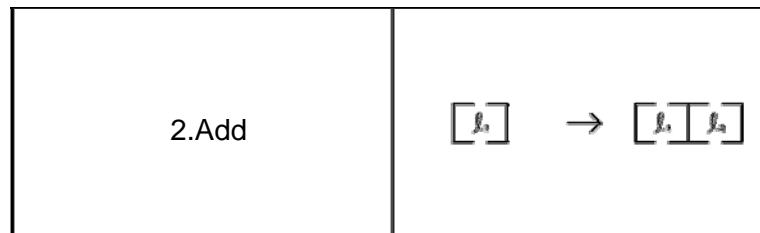
Each rule schema will be analyzed separately in the following sections. First, the rule schemas that describe the architect's general actions will be presented. The description of the rule schemas that refer to the rooms adjacencies will follow.

##### **Rule Schemas**

**Rule Schema 1:** This rule schema describes the parametric character of the used shapes. In that the dimensions of each space can be altered so as to meet both the programmatic requirements as well as the intentions of the architect on the general configuration.



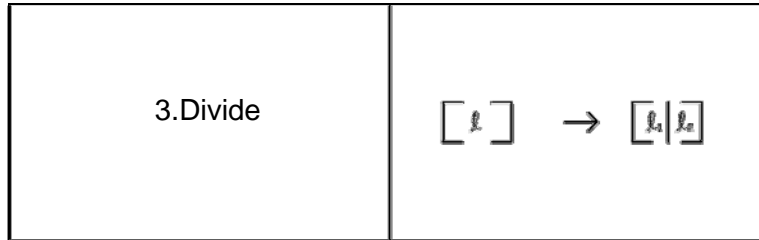
**Rule Schema 2:** The second rule schema allows for space addition, so that a space can be added next to an existing one. The two spaces should have a side in common. The labels of the shapes indicate that the addition happens between specific rooms that are part of the architect's vocabulary of shapes.



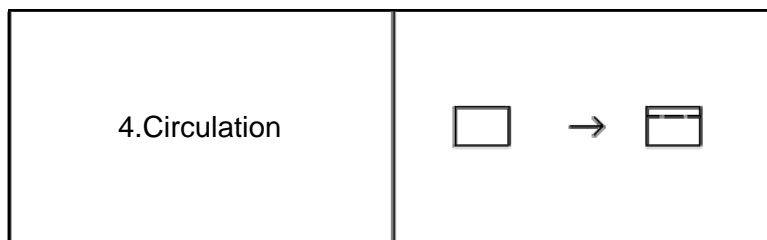
**Rule Schema 3:** The third rule schema allows for space division, so that the shape of a space can be divided into two smaller ones. The labels



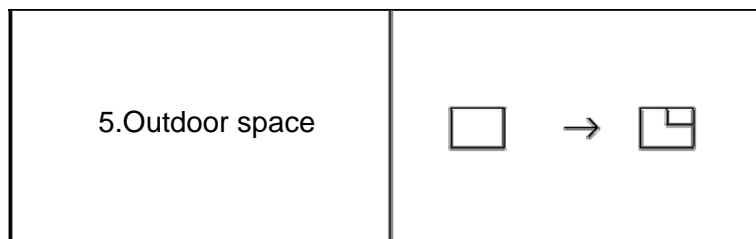
into the shapes indicate that a room can be divided into two different rooms, which are part of the architect's vocabulary of shapes.



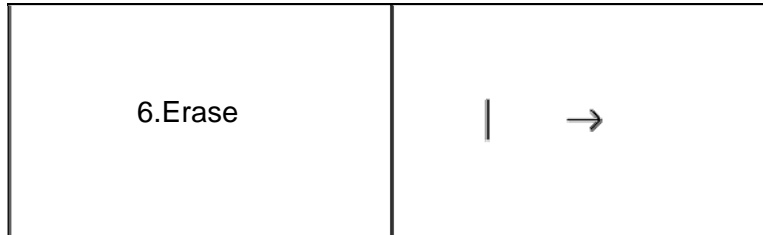
**Rule Schema 4:** This rule schema refers to the action of dedicating part of a room for circulation purposes. A dashed line indicates that a room is divided in two parts, the smaller of which is extracted from the room and is transformed into a corridor.



**Rule Schema 5:** Create a shape into another shape. This action indicates the construction of an outdoor space.



**Rule Schema 6:** The last rule schema permits the action of erase. During the design process the architect can select a line or several lines that he does not want and erase them.



***Rule Schemas: Room adjacencies***

**Rule Schema i:** The dining room can be placed next to the kitchen.

**Rule Schema ii:** The stairs can be placed next to the kitchen.

**Rule Schema iii:** The dining room can be added next to a living room.

**Rule Schema iv:** A bedroom can be placed next to a living room.

**Rule Schema v:** Dining room and stairs can be placed together.

**Rule Schema vi:** A bedroom can be located next to another bedroom.

**Rule Schema vii:** A bedroom can be added next to a bathroom.

**Rule Schema viii:** The stairs can be found next to the bedroom.

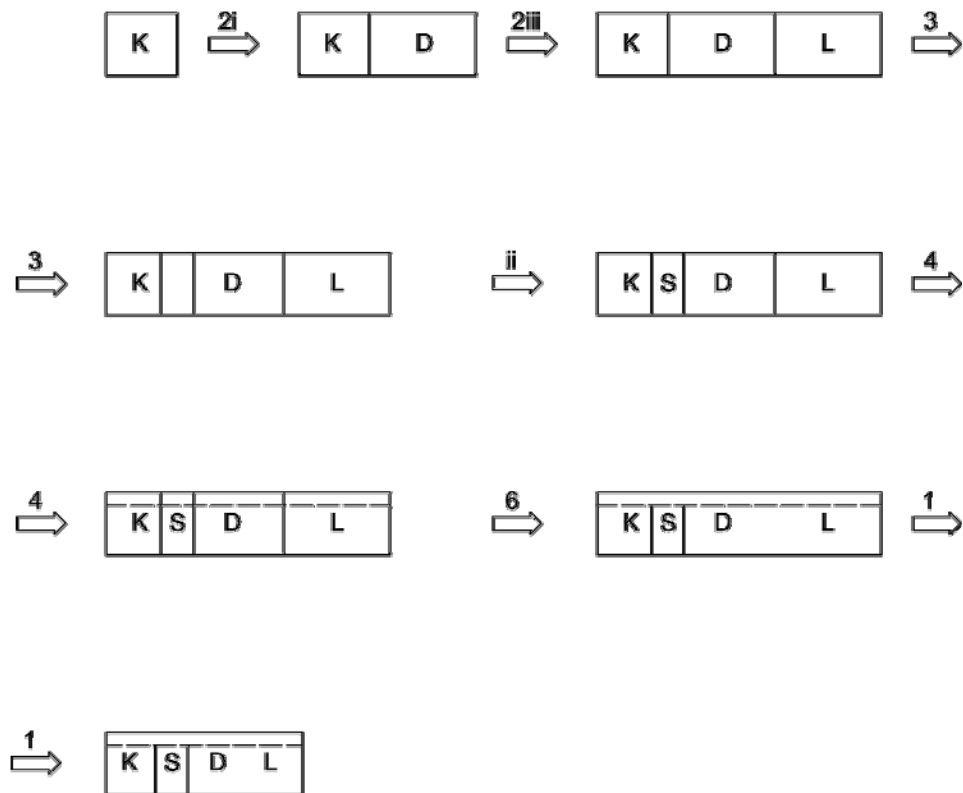
**Rule Schema ix:** The bathroom can be seen next to another bathroom.

**Rule Schema x:** Bathroom can be located one next to the stairs.

***Schematic Derivations***

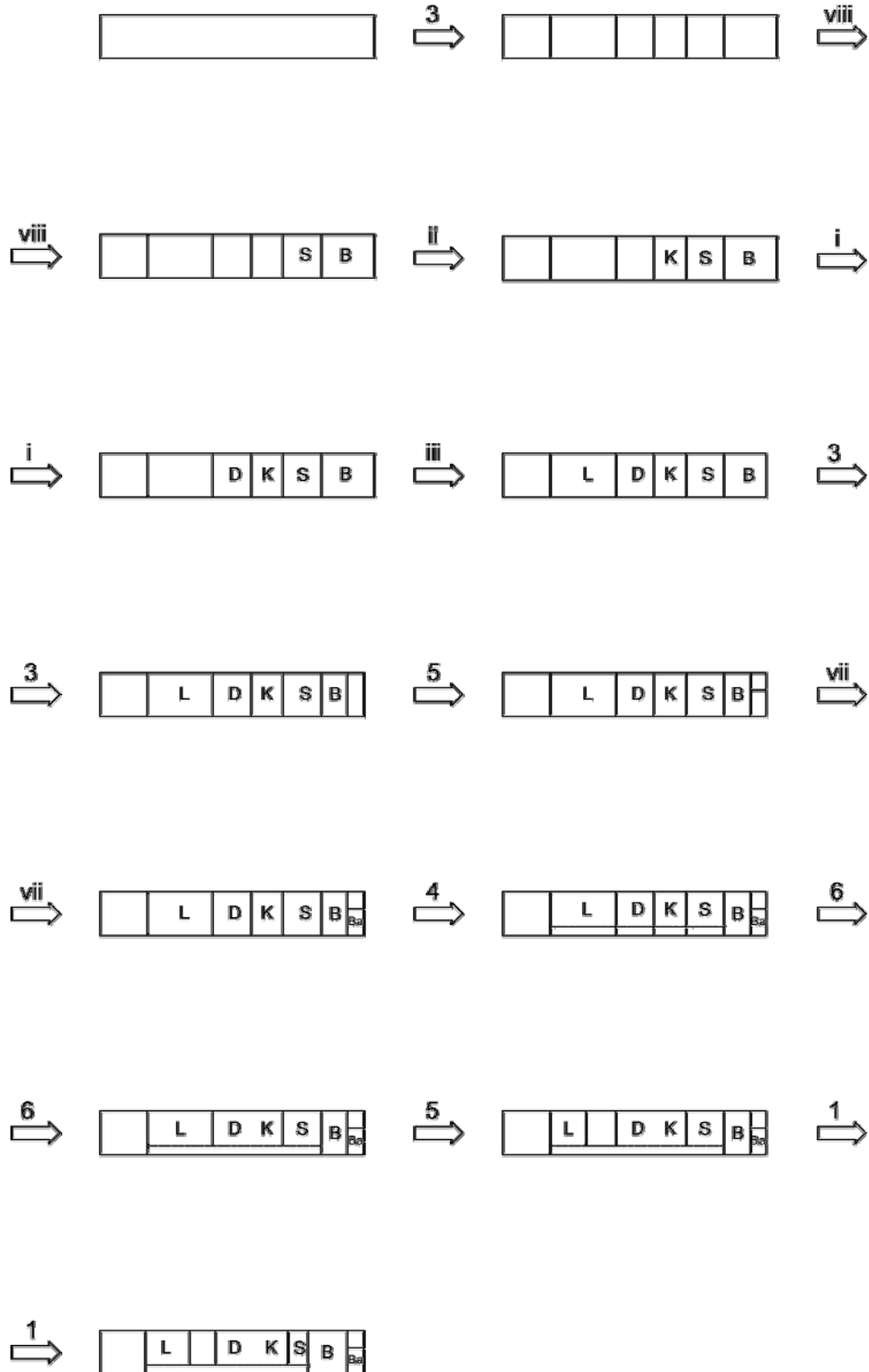
The rule schemas illustrated in the two previous tables (Figure , ) described in the previous section are put into use in each design process. In this section two examples, one for each design problem are presented. The rule schemas illustrated in the two tables serve as organizational principles that formulate the initial vocabulary of shapes into a plan configuration. Working in a similar process with the other architect, architect R was also gradually transforming, in every design step of each design solution, these general rule schemas to specific and explicit application of rules, a process that resulted in the description of the final solution.

**Schematic derivation for the first design solution**





**Schematic derivation for the second design solution**





### 4.3 Process based on personally-derived constraints

Architect P in both design processes used as driving forces constraints originating from a space other than that of the design problem. These constraints referred to either a precedent, a previous image related to a visited space, a typology or the use of the geometrical pattern of a grid. In the next section I will present and analyze the characteristics of each constraint, as well as their contribution to the design process. The next two Figures (30, 31) illustrate the two design solutions of the architect.

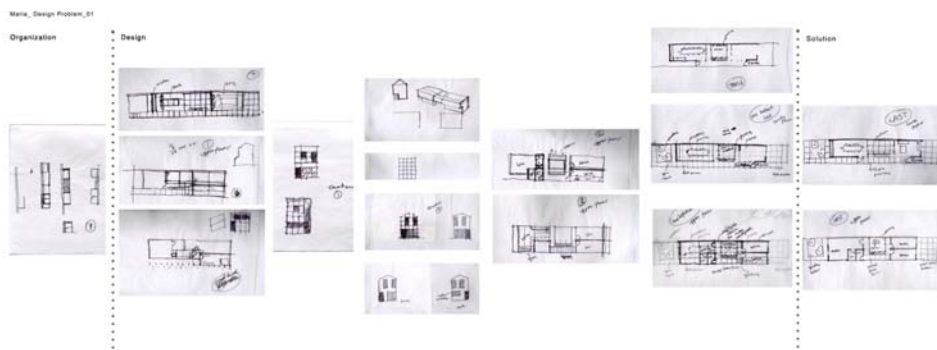


Figure 30: Architect P, Design Problem\_01

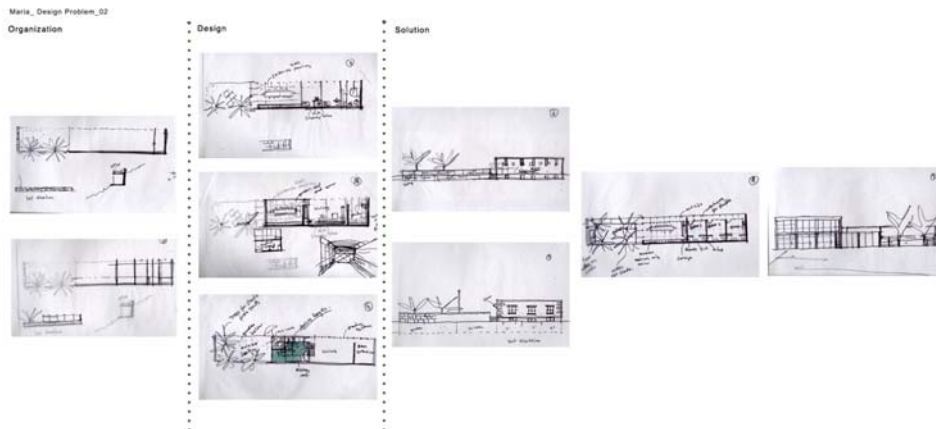


Figure 31: Architect P, Design Problem\_02

### 4.3.2 Design Problem\_01

#### ***Formulation of the problem and organization of design actions***

The architect started by considering the characteristics of the adjacent buildings and more specifically their starting and ending points, so as to decide the location of the site. Soon she let go of about the neighboring buildings and focused on the site itself. Its narrow shape “*fascinated*” her and she wanted to “*...emphasize that, make it thinner, so it would be a stripy thing.*” In order to do that she introduced a narrow walkway at the west side of the site. Having a specific width the walkway was supposed to run throughout the whole length of the site. The architect’s following thought was to place a courtyard next to it, somewhere in the middle of the site (Figure 32). The house would develop on both sides of this open space. The sketch that illustrated this idea was describing a succession of void and solid spaces throughout a site, so that the exact back and forth orientation did not matter to the architect anymore.

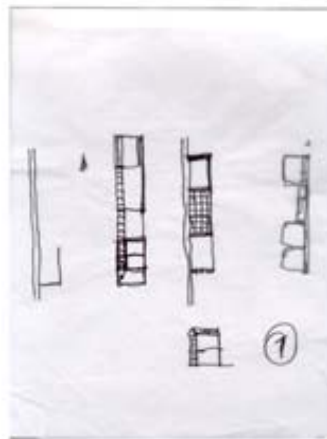


Figure 32: Architect P, Design Problem\_01: Organization

The organization phase ends by the introduction of a 4x4 grid. The idea of the grid came as a continuation of a thought relating to the material that the designer was planning to use, i.e. big slabs of concrete. The architect’s idea was to create a unified space by applying the same floor throughout the site.



The architect's response to the design problem constraints came through two parameters imposed by the designer herself: the idea of the stripes and the geometrical pattern of the grid. The following table illustrates (Figure 33) the two rules that describe the architect's response.

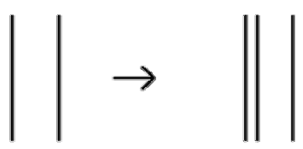
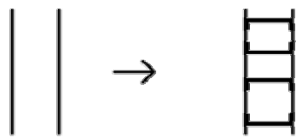
<p>1. Idea of Stripes Corridor</p>	
<p>2. Open space in the middle of the site</p>	

Figure 33: Architect P, Design Problem\_01: Response

### **Actual design**

After the creation of some general guidelines on how she was to proceed with her solution, the architect moved to a larger scale and started drawing the first floor. From the beginning the architect knew that her house would develop in two floors. There she applied all of her previous ideas: she organized the functions of the house around a central open space in relation to a corridor and she drew a 4x4 grid. The result was a house split into two spaces. In the north part she placed the living room and in the south part the kitchen and dining room. Next to the corridor that was running throughout the site and was connecting the two parts of the house she located the stairs that connected the first and second floor.

In the next sketch she moved to the second floor. There she tried several different arrangements of the rooms. She was struggling to specify a satisfying solution, got confused and could not decide on a solution. Her personally-derived constraints came to the rescue: she followed the stripe idea for the location of the two bedrooms on the north side, as well as the open space idea for the organization of the circulation on the second floor. All of her solutions were following the grid and she was always dividing space according to it, placing the circulation in a sub-division (Figure 34).

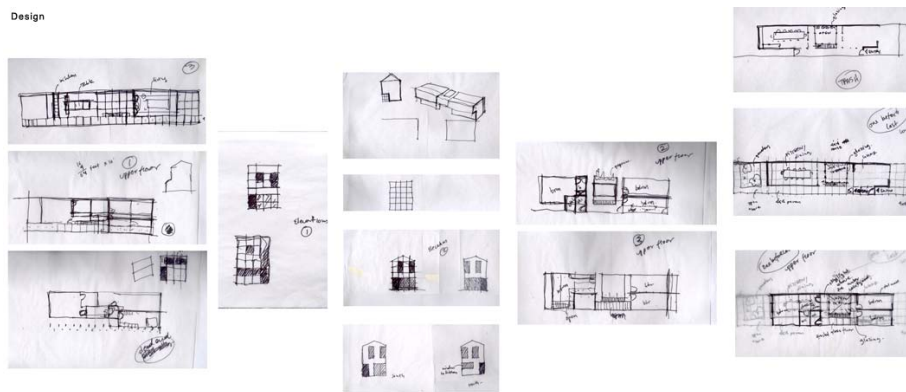


Figure 34: Architect P, Design Problem\_01: Design

The idea of the grid was so strong in the architect's mind that she followed it even in some studies she made on possible elevations, where the openings of the house were following the lines of another 4x4 grid.

In the last two sketches she refined the previous drawings so as to better illustrate her solution. Each sketch provided the description of each floor (Figure 35).

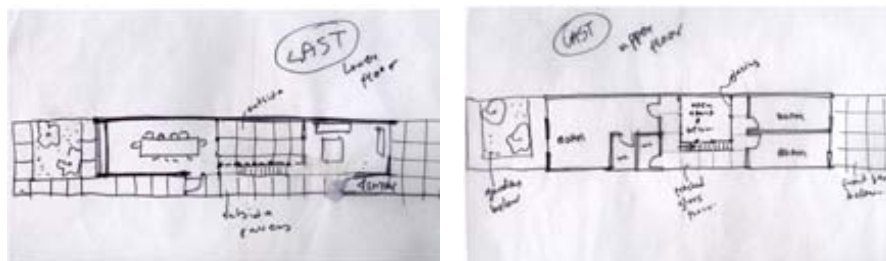


Figure 35: Architect P, Design Problem\_01: Solution

### **Rules in the Design Process**

*“Out of the constraints you get your ideas. That’s where all the interest is. If you have an open... if you can do anything, I do not know...what will you do? You will have to create all of your constraints. That will be hard.”*

The architect developed the design solution by imposing from the very beginning of the design process personal constraints. Some of them came as a response to the design problem, for example the idea of the stripy corridor, as well as the desire to create an open space in the middle of the site. Others constitute design parameters that describe the architect’s general way of working, for example the application of a grid.

Around these constraints the architect formed certain rules that helped her develop and proceed with her solution. The architect was following the rules that she created around these constraints with great consistency. More specifically the application of the grid was guiding the architect in the division of space, as well as in the placement of the circulation. All her actions derived from the lines of the grid. Additionally, the idea of the creation of an open space in the middle of the site served as a guideline of space organization that led the architect throughout the process.

Another rule that the architect was constantly applying was that of using walls in L arrangements. She was using this rule in order to define the space of each room. Although, in some cases, other wall arrangements were selected (e.g. I\_I), the architect’s basic concern was to avoid such situations. In her own words, *“I do that all the time, I am always thinking in terms of thick walls and thin walls...These are like little rules. I like this type of relation, L. I do not like to do that a lot \_I\_, but...it can be done. Of course I do it, but somehow I do not allow myself to do it.”*

### 4.3.2 Design\_Problem\_02

#### ***Formulation of the problem and organization of design actions***

In the second design problem the architect's attention was triggered by the green areas of the site, and more specifically the trees. The architect wanted to provide a bigger space for the garden and that was what she did in her first drawing by defining the garden's position at the north side of the site. This action was followed by the definition of the house's space. The architect conceived the space as having a back and a front. By using a thick black marker the architect drew two lines in an L relationship, which indicated the back of the site. The front was shown by a dashed line, which also demonstrated its transparent character.

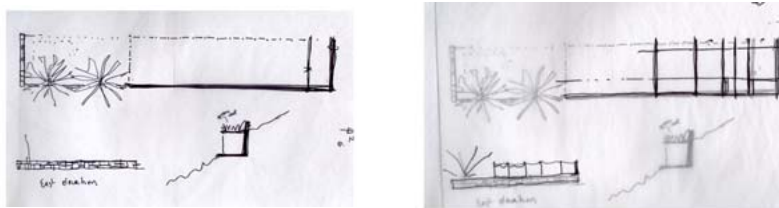


Figure 36: Architect P, Design Problem\_02: Organization

Early in the process, the idea of the vacation room's typology formed the architect's mind. This typology describes rooms located one next to the other in front of a corridor, as she explained *"when you go on vacation and you have the rooms, where you go out of the room to the corridor...so I thought to use that as circulation and I said room, room, room..3 rooms like... during vacation and then should be the kitchen."* The architect at that point thought of proceeding with this idea on the first floor, where she decided to put all the bedrooms and the kitchen and create a more free space for the living room on the second floor.

With the completion of the second sketch the architect had already formed her response to the design problem constraints. Her response was based on a personally imposed parameter, that of a specific typology and is described by the two rules illustrated in the next table (Figure 37).

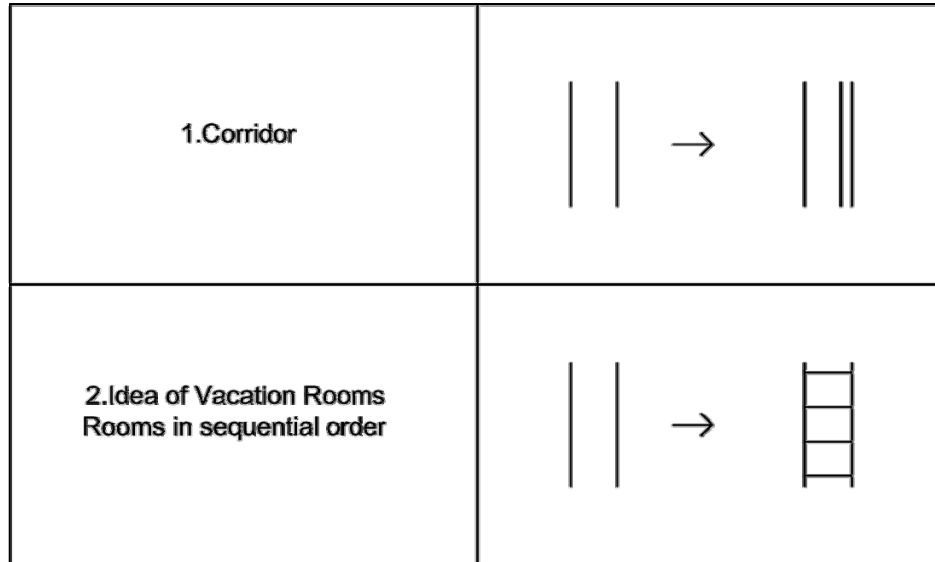


Figure 37: Architect P, Design Problem\_02: Response

### Actual Design

When the moment came to move to the next sketch, so as to further explore her idea, the architect introduced the same 4x4 grid that she used in the previous design problem. In the next two sketches (Figure 38) she tried to find a satisfying way of arranging the rooms both in the first and second floor. She also considered the details of the interior space organization by placing a toilet inside each room. Her wish was that everyone will get the same room, again a characteristic specific to the vacation room typology. The upper floor was limited to cover only the first floors' bedrooms, leaving the kitchen as a one floor space. The circulation, in the form of stairs placed in a ninety degree relationship to the corridor, was located in the space between the kitchen and the bedrooms. As in the previous process, all her actions were formed according to the lines of the grid.

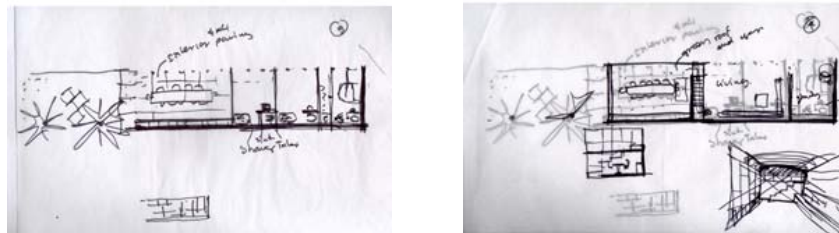


Figure 38: Architect P, Design Problem\_02: Design

The final solution (Figure 39) included a complete plan of the first floor, as well as some studies of possible elevations. An important characteristic of these last elevation sketches is the architect's obvious desire to continue applying the idea of the grid.

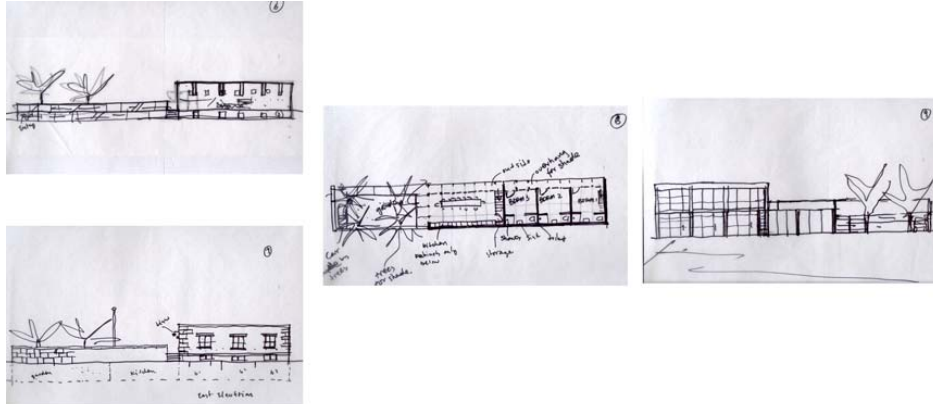


Figure 39: Architect P, Design Problem\_02: Solution

### ***Rules in the Design Process***

Once more, in the second design problem, the architect proceeded with the design solution by imposing early on the design process personal constraints. In this case a precedent served as the impetus to the design solution: the vacation room typology. The architect worked on her solution through the use of a combination of constraints, the typology and the grid application.

For the second time, the architect was defining the different spaces of the house by the use of walls in L arrangements. She used this rule from the very beginning of the design process in her specification of the shape of the house. Furthermore she applied the same rule in the interior space to separate the different rooms.

The use of grid was, once more, a dominant element of her design process. She was following the grid lines in the division of space, as well as in the location of the circulation and the corridor of the house. An indication of the importance of the use of grid in the design process is the architect's attempt to apply its order to the elevation drawings, as well.

### 4.3.3 Rule Schemas

Throughout the design process the architect was trying to make her ideas work. As she said, *“you have an idea, but there is a way it works and you have to find that way. You have to go through a lot of layers to make it work.”* In that path the architect was trying to be as consistent as possible with her ideas. She was gradually moving from a general framework of rules constructed from her own ideas, to their specific application in every design.

In both cases the architect followed a similar design process based on personally derived constraints. The basic rules that characterized and governed both of them became obvious from the comparison of her solutions to the two design problems. The table in Figure 40 illustrates the rule schemas that the architect used while she was working towards the design solution.

A second table (Figure 41) was created to describe the rule schemas that relate to the application of the grid. Grids constitute an important parameter of the architect's process. As the architect stated, *“I love grids. I have to admit. Because it kind of makes you think that this whole thing could be modular somehow and you can take it apart and reconfigure it. I like the mechanics of the grid more than the order of it.”*

The creation of two separate tables (Figures 40, 41) to describe the rule schemas that the architect used was necessary. Although the final design result came from the combination of the rule schemas described in both tables, the grid application constitutes a specific constraint with each own characteristics and set of rules attached to it.






Rule Schemas	
1.Divide	
2.Define space with L shapes	
3.Mirror	
4.Dimensioning a schema	
5.Erase	

Figure 40: Architect P, Rule Schemas



Rule Schemas: Grid	
i. Add a grid	<p>The diagram shows a rectangular frame defined by four corner brackets. An arrow points to the same frame, but now filled with a dense grid of lines.</p>
ii. Add lines on a grid	<p>The diagram shows a 5x5 grid. An arrow points to the same grid, but with an additional horizontal line added across the middle, creating a 5x6 grid.</p>
iii. Place stairs on a division of a grid	<p>The diagram shows a 5x5 grid. An arrow points to the same grid, but with a small rectangular area in the center filled with a diagonal line pattern, representing a staircase.</p>
iv. Cover/Eraser a grid	<p>The diagram shows a dense grid. An arrow points to the same grid, but with the interior lines removed, leaving only the outer boundary lines.</p>

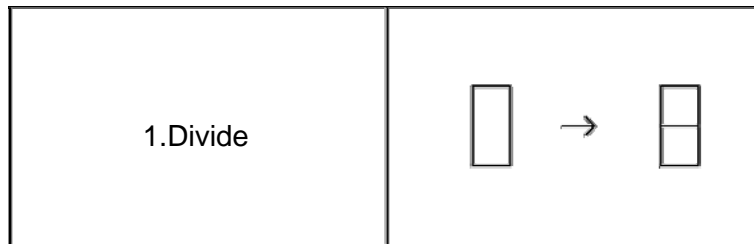
Figure 41: Architect P, Rule Schemas: Grid

#### 4.3.4 Rule Schemas Description

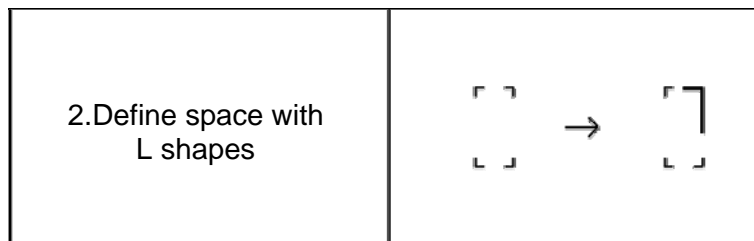
In this section each rule schema will be analyzed separately. First, the rule schemas that describe the architect's general actions will be presented. The description of the rule schemas that refer to the grid application will follow.

##### **General Rule Schemas**

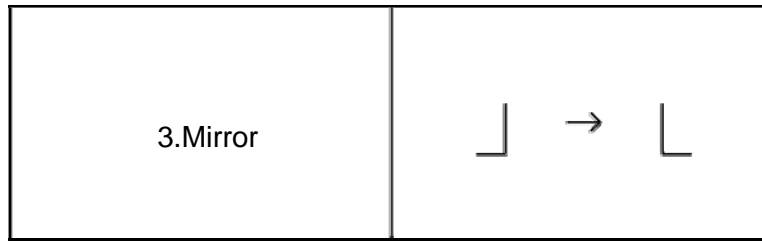
**Rule Schema 1:** This rule schema allows the division of a shape into smaller shapes. The line of division always maintaining a ninety degree relationship with the sides of the shape.



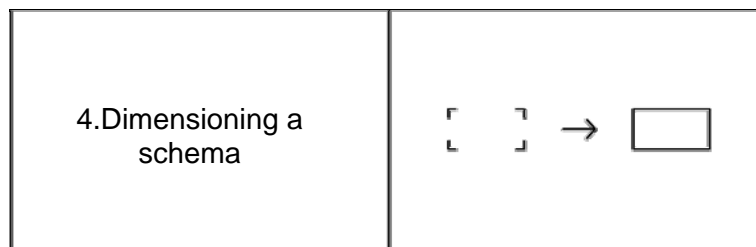
**Rule Schema 2:** The second rule schema describes the architect's use of two walls in an L arrangement to identify space. A general configuration of a shape becomes specific by the definition of its corners through the introduction of two walls in an L relationship.



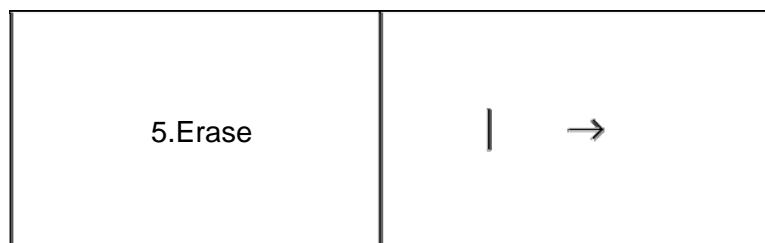
**Rule Schema 3:** This rule schema permits the mirror operation. The shape that describes the ninety degree relationship between two lines can be reflected through an axis to produce the same shape in a mirror condition.



**Rule Schema 4:** The fourth rule schema describes the action of adjusting an initial diagrammatic schema so as to meet the exact programmatic requirements. An initial vague shape could be dimensioned and consequently transformed into different shapes until it is finalized to the one fulfilling both the architect's intentions and the program specifications.



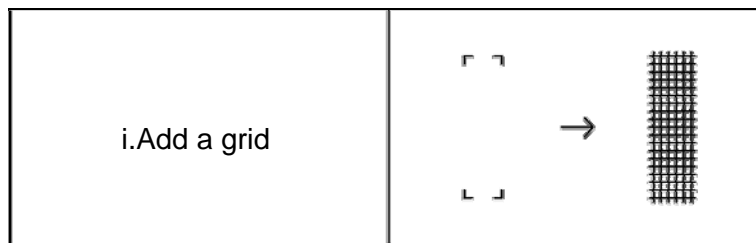
**Rule Schema 5:** The last rule schema permits the action of erase. During the design process the architect can select a line or several lines that he does not want and erase them.



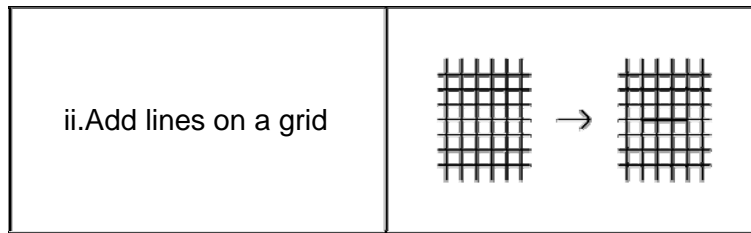
### Rule Schemas: Grid

The use of constraints to organize the architectural elements of a building by establishing successions of logically organized divisions of space is a commonly used design strategy. The grid is one of the most popular constraints of this kind, from the classical period until today. Alexander Tzonis and Liane Lefaivre define the grid schema in their book *Classical Architecture*, as the *taxis* that organizes space through two sets of lines (Tzonis and Lefaivre, 1986). As they continue they makes a distinction between the rectangular and the polar grid schemas. In the rectangular grid schema, straight lines meet at right angles. The distance between these lines is often equal, cutting the composition into equal parts. In the polar grid schema the one set of dividing lines forms concentric circles, while the other radiates from the common center of these circles (Tzonis and Lefaivre, 1986). The value of using such a constraint in the design process lies in the fact that it introduces proportion and scale to the spatial configurations, without providing exact dimensions to the configuration. Architect P is using the first type of grid schema, the rectangular one. The rules that derive from this application are analyzed and described below.

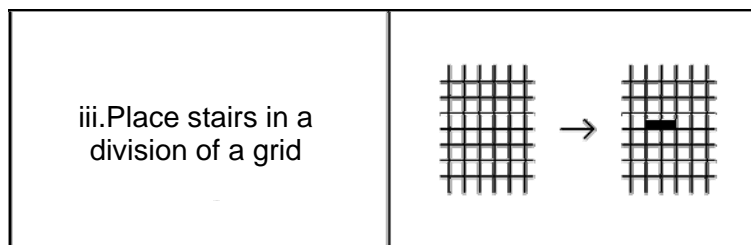
**Rule Schema i:** This rule schema describes the addition of a grid into a shape.



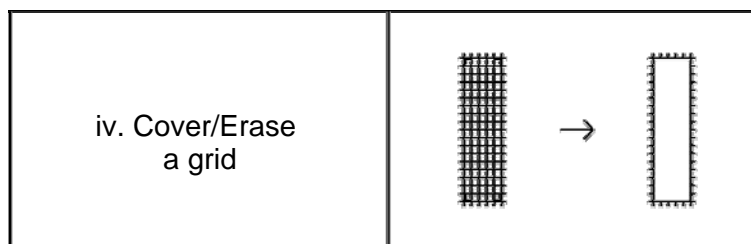
**Rule Schema ii:** The next schema allows the addition of lines on a grid. The addition can happen both on the top of the actual grid lines, or in a division of the grid.



**Rule Schema iii:** Add a stair on a grid. This addition can occur either on the grid or in a division of it.



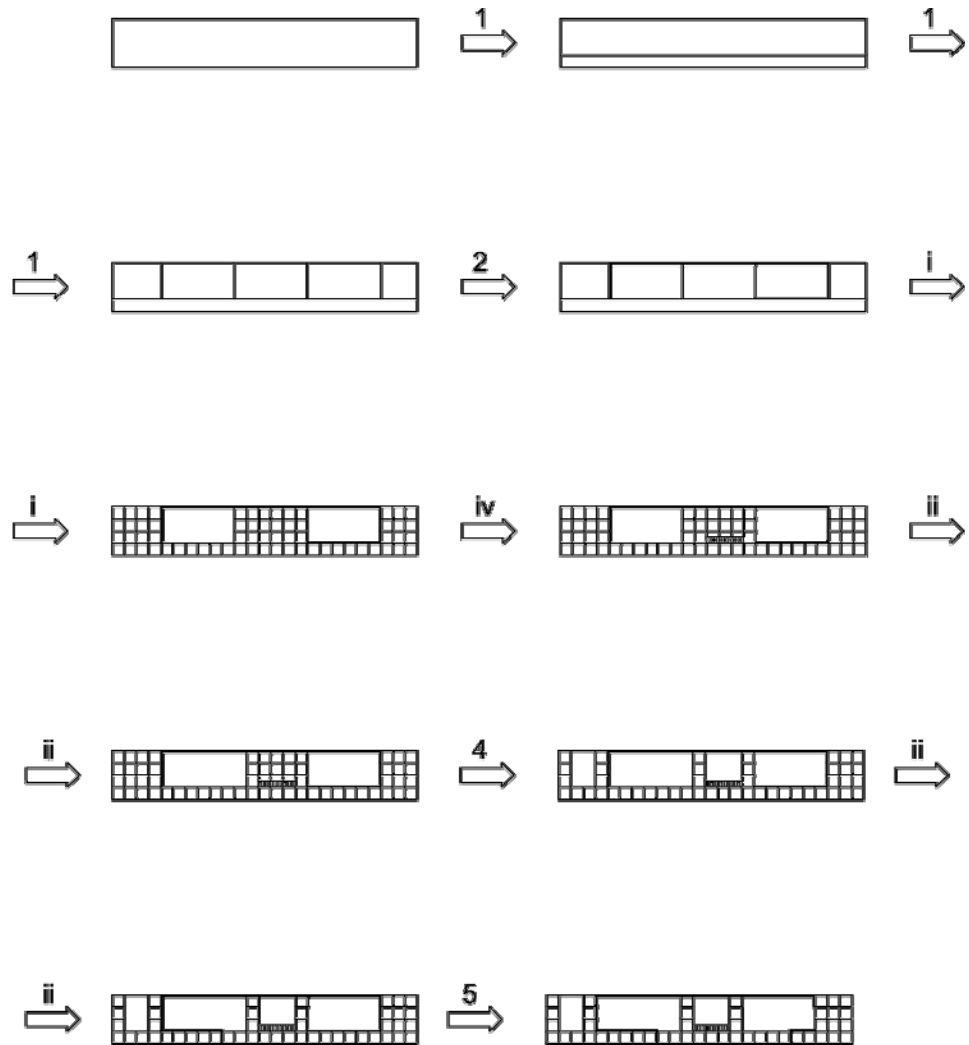
**Rule Schema iv:** The last rule schema covers the deletion of a grid. This action relates to the intention to differentiate between spaces, for example as to distinguish an interior from an exterior space.



### ***Schematic Derivations***

The architect proceeded with her design process by combining the rule schemas described in the previous sections. In every design problem she was putting the rule schemas into action so as to create plan descriptions. In every design step, the selected rule schema was gradually taking the form of a specific and explicit rule. In this section two examples, one for each design problem are presented.

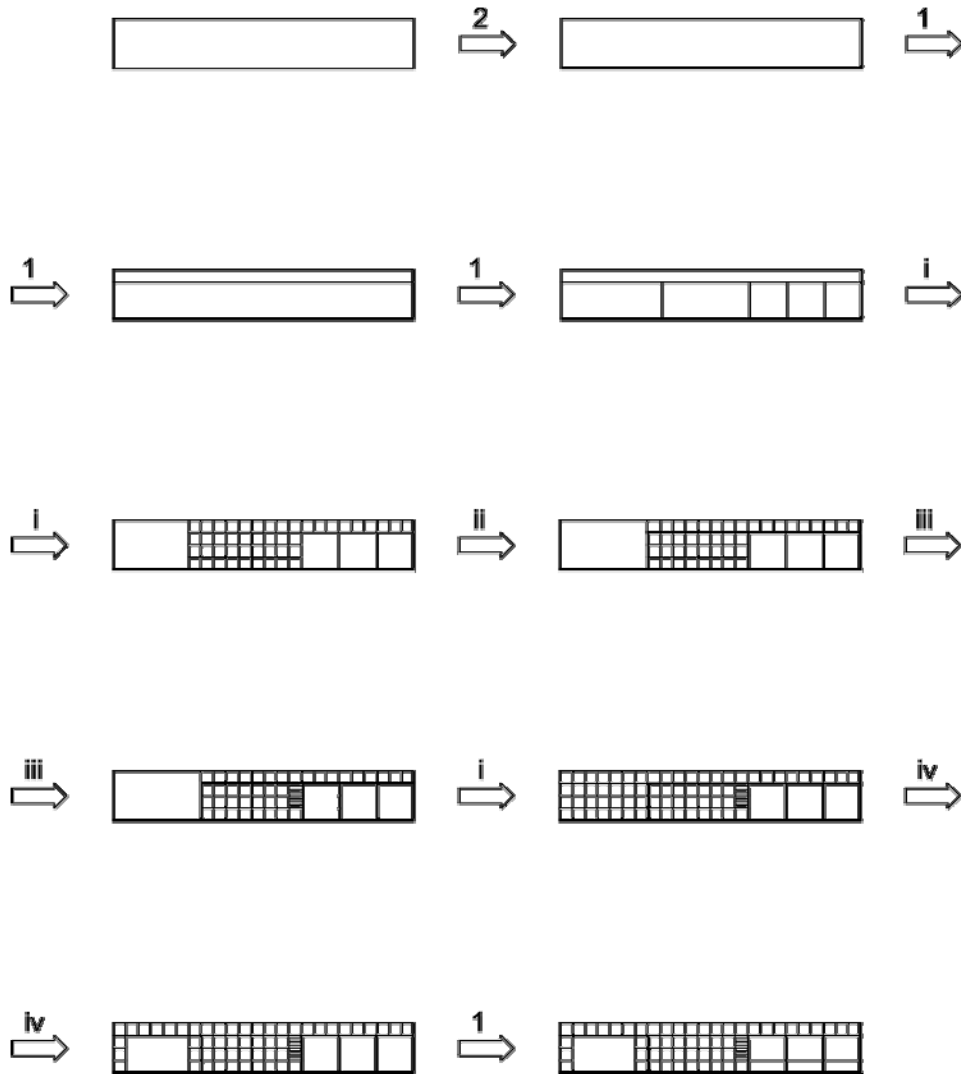
**Schematic derivation for the first design solution**







**Schematic derivation for the second design solution**





#### 4.4 Discussion

In each of the three examples presented, the architects formulate their **responses** to the design problems by creating a framework based on different types of constraints. In the first case the architect's response was the creation of a house with an open space in the middle, an idea that derived after studying the parameters of the site; in the second case the programmatic constraints led the architect to the organization of different blocks of space as an answer, and in the third case the introduction of certain typology together with a precedent relating to the site's shape formed the architect's response. The above frameworks had the form of a general and flexible set of rules that determined a broad area in which the architects could explore their solution.

Apart from the general set of rules that the architects' developed around the constraints in the form of a response to the design problem, other sets of rules were also created that referred to the **personal design methods** of each architect. Once more these sets of rules provided a design framework by describing spatial relationships in a general manner and could thus be represented by Rule Schemas. For example, in the first case an important rule schema was that of the use of bilateral symmetry; in the second case the operations of addition and division; and in the third case the rule schemas that develop around the arrangement of walls and the grid application.

In all three cases, the rule schemas that were formed around the different constraints were combined with the rule schemas describing the architects' personal design method. The **combination** of the two provided the guidelines towards the design solution. It appeared that the constraints served as an impetus for the architects to impose their personal design method. This fact does not mean that the rule schemas corresponding to the constraints were abandoned, but rather that they were incorporated in the personal design method of the architect.

Interestingly enough, the three novice architects developed a different design process. In the table of the design activities (Figure 7)

the novice architects are placed under the group of program-derived constraints. Their process was characterized by their efforts only to solve the programmatic constraints of the design problem, without imposing any other design method, perhaps because they have not yet developed one. They therefore grasp upon the programmatic constraints and try to provide a design solution based only upon them.

Returning to the three previously analyzed examples, the architects created frameworks that provided general methods of approaching the design problem and could be described by Rule Schemas. A basic characteristic of these rule schemas is that they create **qualitative descriptions** of the objects under construction. This means that during the design process the object is not defined by explicit rules and norms, but rather with a schema that describes its general aspects. The benefit of this feature is that it leaves space for an idea to evolve and to become something new and different, rather than locking an idea to specific expressions. It provides a way of thinking on something, rather than providing a definite solution for it. In that sense, qualitative descriptions allow for different interpretations. For example, bilateral symmetry could be applied in almost every situation that describes a reflection across an axis, from a human body to a classical architectural plan, without defining the exact way of its application, but just providing a guideline to work with. Similarly, the use of grid, gives a sense of scale and proportion without fixing things in specifying relationships. An interesting and inspiring use of grid is illustrated in the work of D'Arcy Thomson in his studies on form. Thomson (Thomson, 2000) studied the different forms of related animals as a result of mathematical transformations of a grid (Figure 42).

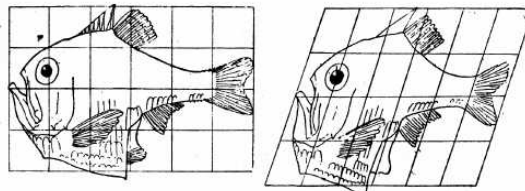


Figure 42: D'Arcy Thomson: Form exploration

The rule schema describes an area of possible design actions. The **general** spatial relationships captured in it become more **specific** through the use of rule schemas in different occasions. From a schematic organization to the actual design the rule schemas are gradually refined to express specific rules that characterize the final solution. In the case of architect D for example, the use of bilateral symmetry at the beginning indicated the perception of the site as a shape divided by a symmetrical axis. Gradually, and in relation to the other rule schemas, this idea became more specific and finally took the form of a symmetrical house with two similar structures at the two sides and another one connecting them. Architect R had a rule schema in his mind determining the average square footages of each space and another defining their relationships. These general spatial relationships gradually took the form of specific rooms with fixed dimensions through the use of certain design operations that related to the architect's design methods. In the third case, one rule schema that the architect constantly uses is that of the L arrangement of walls to define a space. This general idea about the boundaries of a space became explicit in each of the two problems: in the first case describing the boundaries of each room, while in the second the boundaries of the whole house.

The three analyzed examples prove that architects use rules during the early design phase. The characteristic of these rules, as stated previously, is that they gradually move from a schematic description to a specific one. The developed shape grammar managed to capture this transformation from general to specific by rule schemas that convert gradually to specific rule via their application in design. Furthermore, the shape computation shown offered a formal way of describing design composition from scratch without imposing any specific design procedure, but rather by adjusting to the special design process of each architect. This is beneficial because, as was extensively analyzed in the second chapter, architects do not follow a specific path to reach their

solution and so need tools and processes that can adjust to their personal way of designing.

## **5. Perceptual Design Events**

Throughout the design process, just from the point the architect takes the pencil and designs the first line until the creation of the final solution, perceptual design events occur that inform and enhance the design process. I use the concept of perceptual design events to refer to the feedback process in design, which was extensively analyzed in the second chapter of my thesis. I argue that these events are very important and beneficial for the design process and serve as an impetus for its development. Architects constantly make use of perceptual design events in an either conscious or unconscious way.

A central characteristic of perceptual design events is that they relate to the notion of emergence, which is connected with novelty and unpredictability. For that reason, it is considered an essential part of creative design. The concept of emergence, however, is difficult to describe exactly because of the way it occurs and the reasons for its emergence are not precise. Philosophers, even from the nineteenth century, attempted to provide a definition for this notion (Knight, 2003). The most popular current one was expressed by John Holland, more than a century ago, and is described in Knight's article "Computing with emergence." According to Holland, "occurs only when the activities of the parts do not simply sum to give the activity of the whole. For emergence, the whole is indeed more than the sum of its parts" (Knight, 2003).

The notion of emergence is central in the discourse about computational models that intends to provide design descriptions. The fact that the properties and the characteristics of emergence cannot be described explicitly, as it occurs under different situations, makes the automation and computability of the processes that emergence imposes extremely difficult. I believe that the observation and categorization of different types of emergence that happen during the design process could enrich the ongoing discussion as well as the understanding of the concept.

Perceptual design events were observed in the processes that the architects employed in the experiment. Their analysis helped me distinguish between two types of perceptual design events. The first one refers to immediate design events and the second to archived ones.

The immediate design events relate to real time feedback relationships. In other words, as the architect is in the process of designing she sees a new relationship in her drawing and decides to rearrange the configuration and examines the new situation that she observes. She, therefore, proceeds by immediately informing her drawing.

Immediate design events usually involve shape emergence. An emergent shape is a shape that is not specified as an initial element used in the design, but one that arises from the shapes generated by these initial elements. It is usually seen by the architect in the design and depicted as a separate element from the whole configuration (image).

The second type of perceptual design event is that of the archived one. This type refers to the stored knowledge gained in a previous design situation and its use in a similar case. More specifically, the architect informs the design process with the knowledge that she already has. This fact may result in the emergence of a different process with which the architect is going to proceed with the solution.

The following section presents two examples of immediate perceptual design events, which occurred in different stages of the design process and one example of the archived type of event that happened between the two design problems.



### **5.1 Immediate Events: example\_01**

The first example of an immediate design event occurred during the organization phase of the second design problem conducted by architect D. The event served as an impetus; the idea helped the designer organize his further actions towards the design solution.

After having read the design problem and familiarizing himself with the requirements the architect put a tracing paper on top of the general site plan. He started tracing lines so as to identify the special conditions of the site and to find an idea about how to proceed with his solution. One of his first moves was to draw the rectangular shape of the site (Figure 43). He continued by examining the sea cost, the slopes, the solar orientation, and the neighboring buildings. At that point, he realized that the views of the neighbors constitute an important parameter of his design and he somehow had to incorporate it in his design solution. Therefore he made a decision: his house should not block the neighbors' views. He drew an axis into the site (Figure 44) showing the main direction of the neighbors' views. His next move was to trace two lines in an angle indicating the broader area of the views. By that time the architect knew that his house will be located at the two ends of the site – north and south – leaving the space in the middle open to allow the neighbors' views. The architect, however, did not have a specific idea about the exact shape of the house. The idea came in an unanticipated way.

The moment the architect drew the two lines to indicate the neighbors' views (Figure 44), two symmetrical quadrilateral shapes emerged (Figure 45) at both sides of the site. The architect realized their existence and took a red marker so as to clearly identify them. He liked their shape and thought that they could host the functions of the house. The architect's final decision was to proceed by using these two shapes and incorporate them in his final solution.

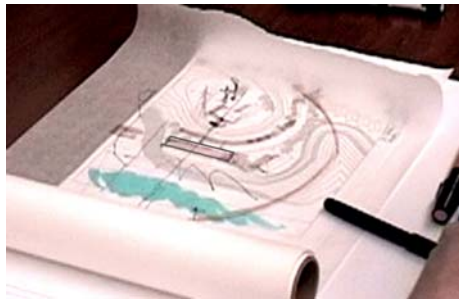


Figure 44: Draw the site

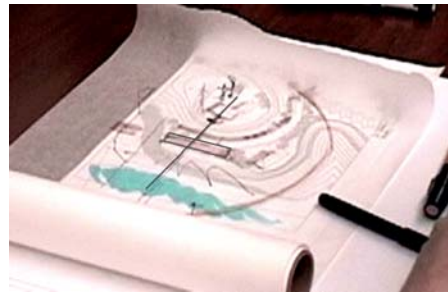


Figure 45: Draw a symmetrical axis

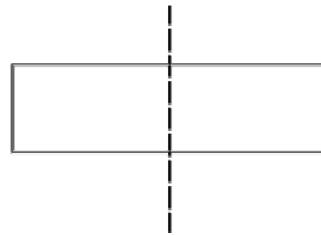


Figure 43: Draw two lines, indicating view's area

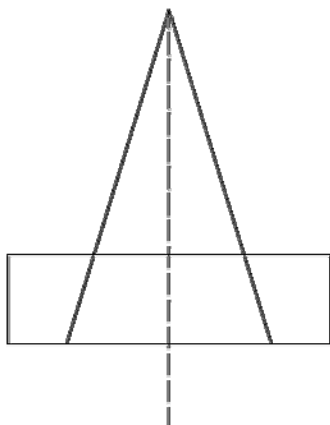
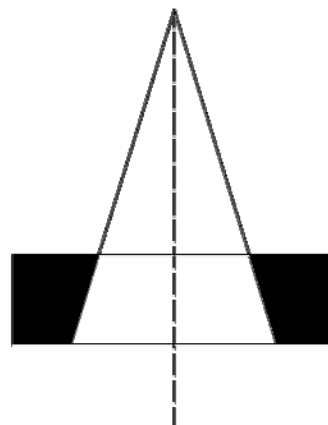


Figure 46: Shape emergence



When the architect was asked to describe the process that led him to the design solution, he did not mention explicitly how he decided on the house's shape. He just explained that he did not want his house to block the neighbors' views so he proceeded with that specific configuration. Only after he was specially requested on how he created the particular form, he explained and actually realized that the form had emerged from the two lines. What is worth comment at this point, is that the description of the rules governing the final solution are different from those that refer to the description of the process. The architect described his final solution and justified his actions towards the solution in a very explicit way. The design process, however, is described by more unclear rules and situations that inform design through their gradual transformation.

### **example\_02**

A similar example of an immediate design event occurred during the actual design phase of the second problem, designed by architect O. This event describes the architect's action of incorporating a mistake into her final design solution. As she was working on the first floor plan, the architect decided to expand the house outside the site's boundaries by offsetting the north west corner (Figure 47). At this part of the house the architect had located a patio because she thought that corner provide the best views of the ocean. The architect's action of expanding the patio, therefore, related to her intention to take advantage of the views, as well as to add "some extra drama" as she later explained. This extra drama however, proved to be a serendipitous moment. How?

When the architect moved to the second floor, she placed a new tracing paper on top of the first floor sketch. While solving the second floor, she traced the boundaries of the extra line of the patio underneath it by mistake and she developed her solution according to it (Figure 48). After a while, she realized the mistake and redesigned the floor based on the original boundaries. The rooms, however, did not fit and so she decided to return to the previous solution and to integrate this mistake into her proposal. In her final solution, illustrated in the section (Figure 49), the second floor expands over the first.

An interesting issue related to the design process is that when the architect was asked to describe her solution she did not mention the mistake. On the contrary she said that she decided to expand the second floor because she wanted to take advantage of the views. Only when we saw her explain what originally in the video tape did we realize this. As in the previous presented perceptual event, this situation illustrates that the description of the final project and the description of the process that led to it are fundamentally different. While the description of the final object refers to concrete rules and norms that characterize the synthesis and the process that led to it ("I expanded the second floor so as to take advantage of the views"), the true description of the design process is

characterized by vague rules, by rule schemas that continuously change so as to meet the intentions of the architect and the requirements of the design problem.

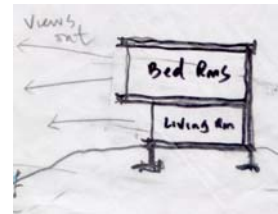


Figure 49: Section

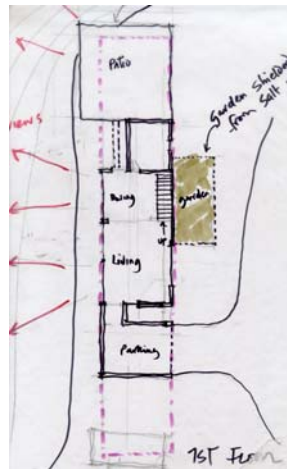


Figure 47: First floor

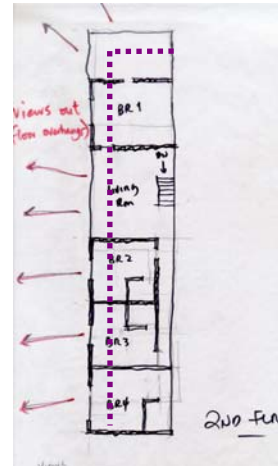


Figure 48: Second floor



## 5.2 Archived Events

A different type of perceptual design event happened in the case of the architect R, between the two design problems. The event refers to the stored knowledge of a previous design situation, its recall and use in a new situation. In the first design process the architect started by organizing the programmatic requirements of the design problem. The second action of the architect was to create blocks of spaces and to estimate their approximate sizes. In order to organize these spaces into a whole, the house, the architect proceeded with the adding operation (Figure 50). He started with a specific space and then was continuously adding other spaces next to it. This process led him to the creation of the final solution. As long as he found a satisfying solution the architect stored it in his mind.

Moving to the second design problem, the architect had to deal with a similar design situation. He recalled the previously gained knowledge and applied it to the new problem. At this point, an interesting situation occurred. The architect altered his design process and continued in both a similar and different way. Although his primary concern was still the organization of the programmatic requirements, he did not proceed by calculating the average sizes as he already knew them and also did not apply the add operation. On the contrary, he proceeded with the divide operation (Figure 51); starting from a shape he was gradually dividing into smaller shapes so as to accommodate the house's functions. In conclusion, the use of stored knowledge in the second design problem resulted in the emergence of a process; the architect switched from the adding operation to the dividing one.

### Design Problem\_01

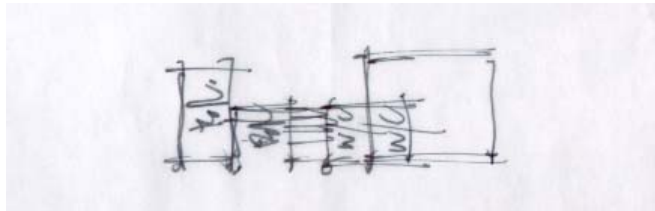


Figure 50: Adding Process



### Design Problem\_02

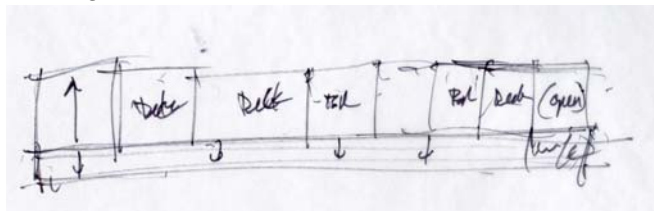


Figure 51: Dividing Process



### **5.3 Discussion**

Three cases of perceptual design events were presented in this section. The motivation for their presentation in a separate chapter of the thesis was so as to illustrate their significance as important features of the design process. Of course the discourse around this type of event and their importance in design is not a new one. My experiment, however, proves that these events actually happen during the design process and that they inform in a positive way the final outcome. Furthermore, the analysis of the experiment helped me create a distinction between two different types of perceptual design events: the immediate and the archived ones. The immediate design events have to do with the real time feedback, that is the architect immediately alters the design and incorporates the new situation into the solution, while the archived ones communicate stored knowledge and its use in a new design situation.

In both types the notion of emergence was apparent. In each case, though, it referred to different situations. In the immediate type, emergence related to shape creation, while in the archived type referred to process application. Although the two emergent situations seem to have nothing in common, they relate in the impetus that led the architects in their creation; the seeing situation. A basic characteristic of the design process is that the architect proceeds in a “what you see is what you get” way. This process is evident in all three cases; in the first example, the architect saw a new shape in his design, depicted it and incorporated it into his solution. In the second example, the architect saw and drew “a wrong” line and proceeded with that in her solution. In the third example, the architect saw a site, the shape of which reminded him of a previous similar one and decided to apply the previous solution in that. Emergence in design, therefore, strictly relates to what the architect sees each time in her design.

An interesting observation that occurred during the interviews has to do with the description both of the final solution and the design process that led to it. The two descriptions have a major difference; while



the one that refers to the final object involves explicit rules and definitions on the relationships that determine the compositional parts, the description that refers to the design process implies more implicit and vague rules, which constantly change. In other words, the design process involves rule schemas, vague descriptions of a relationship, which could be followed, altered, or abandoned throughout the process. In the description of the final result, on the other hand, these vague schemas take the form of explicit rules. The architects have the tendency to forget the reasons that guide them to certain decisions and in fact translate them in a way that supports their final design. What is really happening though, is that the design process is continuously informed by and changed due to different perceptual design events that impose new general rule schemas in the process and enhance the path towards the final solution.

## **6. Conclusions**

The scope of this research was to identify the role of rule-based processing in the early phase of the design process. Driving force behind this inquiry was the observation that computers and computational processes are rarely used in those stages. A significant reason for this is that the early design processes involve implicit and ambiguous rules, while design processes that happen inside a computer demand explicit rules. It appears, however, that rules constitute an underlying factor of both procedures and so the thesis question was whether or not rules can become the vehicle for the connection between the two. By means of the case study experiment on the processes that professional architects employ when working towards a design solution, and the analysis of these processes regarding the use of rules, I made the following observations.

Professional architects formulate design frameworks based on problem or personally derived constraints so as to respond to the design problem. These frameworks have the form of a general and flexible set of rules that determine a broad area in which the architects can explore their solution.

Throughout the design process, in addition to a set of rules that relate to the design response, architects also form new ones to help them proceed with their solution. These new sets of rules relate to the personal design methods of each architect, describe spatial relationships in a general manner and can be expressed with general rule schemas.

Architects proceed in their design solutions with a combination of the different rule schemas they develop throughout the process. This interaction provides the guidelines upon which the architects may reflect so as to continue with their drawings. The constraints and the initial rule schemas formed around them serve as an impetus for the architects to apply their personal design methods. This fact does not mean that the initial rule schemas are abandoned later in the process but rather that they are incorporated into the general design method of the architect.

Interestingly enough, novice architects that have yet to establish a concrete design method, proceed in their solutions based mostly on programmatic constraints.

The analysis of the design solutions proved that architects do use sets of rules during the early phases of the design process and also demonstrated two of their important characteristics. The first one is that these sets of rules do not define the specific properties of the object under construction, but rather describe some general spatial relationships. In that sense, these rules provide a broad method of approaching the design problem. They could be illustrated by general **rule schemas**, which offer **qualitative descriptions** of the object under construction without specifying its exact characteristics.

The second feature of these sets of rules (rule schemas) is that the general description they provide progressively becomes more specific through their application in different occasions. From a schematic organization of the design problem to the actual design of the object, the rule schemas are gradually refined to express specific and **explicit rules**.

This last observation is supported by the different descriptions in terms of rules that architects employed to define their design processes and the final objects during the interviews. The final objects imply concrete and distinct descriptions, with explicit rules and norms that define the final composition, while the processes that lead to it include vague and ambiguous descriptions with rules that refer to a broad area and lead to schematic derivations. An interesting observation was that architects are not always conscious about this qualitative character of the rules used in the early design process; they seem to forget the events and incidents that altered their design process and present it as a concrete procedure that from the beginning to the end was following the same specific norms and was meant to result in a specific artifact.

The above described features, the qualitative descriptions and the gradual movement from general to specific, are extremely beneficial for the design process because they allows ideas to evolve by providing a

general way of thinking without fixing them to specific form descriptions. In that context, re-interpretation of a design situation is supported and may thus easily occur. This last assumption was supported by the design solutions of the experiment.

The design process is also constantly informed and enhanced by **perceptual design events**. These events relate to the feedback process, an essential characteristic of creative design. During the experiment two types of perceptual design events were observed: immediate and archived. Immediate design events refer to real time feedback, while archived ones relate to stored knowledge and its use in new situations. Both types of perceptual design events relate to design emergence: shape and process emergence respectively. The occurrence of perceptual design events is strictly related with the act of seeing. The architect proceeds in her solution by seeing (a new spatial relationship, a design mistake, a similar site), picking up the different design situations and incorporating them to her final solutions. It is a process based in the “what you see is what you get” type of relationship.

The qualitative feature of the rule schemas used at the early design phase, together with the rules’ movement from general to specific constitute design characteristics which are hard to automate; a rule or an algorithm demands an explicit specification of the involved elements. The task of automation becomes even harder when the discussion includes the perceptual design events: how can an unanticipated event ever be automated? Nevertheless, the present thesis successfully demonstrates that it is indeed possible to develop a shape grammar that comprehensively describes the early design phase and its products.

In the present thesis I developed a computational model based on shape calculation that provided successful descriptions both of the design process and the final outcome. Rule schemas were used to describe the architects’ design activities from the starting point of their process to the completion of a satisfying solution. Furthermore, these rule schemas managed to incorporate the occurrence of perceptual

design events. The examples presented in my thesis thus demonstrate that it is possible to automate design composition from scratch without sacrificing the important features of creative design activity, those of ambiguity and emergence. The study of rules, of their characteristics and their involvement in the design process, served more as a guideline throughout this process, instead of a strict instruction. The implication being that rules are more than just concrete definitions of a situation, but rather also refer to general descriptions without loss of significance or power. This becomes obvious if one interprets a rule schema as the overarching structure wherefrom specific rules can be derived.

*“Contrary to conventional wisdom, rationality does not flourish in the presence of objective certainty, but actually thrives around subjective volition. To be rational requires the willingness to restructure the world on each contingent occasion, or in just two words, to design.”*

*Lionel March*

I believe this work can serve as a starting point to investigate the early phase of the design process and how we can create computational models to effectively address it. Further study of the role of rules in different design situations, such as when architects work in groups, together with the examination of the occurrence of emergent design events can open new avenues on the use of computation in the creative design phase.



## **Appendix A. Consent Form**

### **CONSENT TO PARTICIPATE IN NON-BIOMEDICAL RESEARCH**

#### **Designing with Rules**

You are asked to participate in a research study conducted by George Stiny, Professor of Computation and Magdalini Eleni Pantazi, graduate student, from the Department of Architecture at the Massachusetts Institute of Technology (M.I.T.). You have been asked to participate in this study because you are a professional architect. The approximate number of the participants in the study will be 7. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

- **PARTICIPATION AND WITHDRAWAL**

Your participation in this research is completely VOLUNTARY. If you choose to participate you may subsequently withdraw from the study at any time without penalty or consequences of any kind.

- **PURPOSE OF THE STUDY**

The purpose of my study is to understand the strategies that architects use in order to solve a design problem in the early phase of the design process. More specifically I want to explore the role of rule and of patterns of rules in this exploration phase.

The identification of patterns of rules in design will provide an insight in the design process. This fact will help in reconsidering the relationship between the design process and the available design tools. Better understanding of the process will lead in the improvement of the existing tools or even in the creation of new ones capable of addressing the architects' needs.

- **PROCEDURES**

If you volunteer to participate in this study, we would ask you to do the following things:

The experiment consists of the following three phases:

1) You are asked to solve a design problem in a one-hour session. You can use whatever design tool you want (paper and pencil, computer or both). In order to keep track of the process that you follow towards solving the problem, a video camera will be used to record your design decisions and moves.

2) You are asked to solve another design problem in a one-hour session. The second design problem is a transformation of the first one. Again the process will be recorded.

3) I will meet with you and review the process you followed, with the aid of the videotapes. More specifically, while watching the videotapes, I will ask you to describe the moves and the decisions you took during the design process. I will only take part if I observe that you skipped a design event without commenting on it and I will ask you to describe it.

- **POTENTIAL RISKS AND DISCOMFORTS**

You will be asked to act as you normally do when you have to solve a design problem. In that sense there is no risk involved.

- **ANTICIPATED BENEFITS TO SUBJECTS**

Based on experience with this process professional architects or students of architecture researchers believe it may be of benefit to them. The potential benefits may include a better understanding of the design process that each individual follows. Through the experiment process you may gain a different perspective of your personal design processes.

It is very likely, however, that you will not improve your design processes through the participation in the research.



- **ANTICIPATED BENEFITS TO SOCIETY**

The past two decades, new tools were introduced in architectural design process. The processes that architects used, however, have not changed. As a result these new tools are not used in their full potentials. Better understanding of the strategies that architects employ in the design process will help in improving or even inventing new tools and this fact has beneficial results both for design education and practice.

- **ALTERNATIVES TO PARTICIPATION**

There are no other alternatives to participation.

- **PAYMENT FOR PARTICIPATION**

While my primary goal is to use the experimental results to support my thesis, I also plan to publish these findings in a referred journal, citing all participants and acknowledging the Affinities group (the research group, part of the architectural firm with which I will work) as sponsors.

- **PRIVACY AND CONFIDENTIALITY**

The only people who will know that you are a research subject are members of the research team. No information about you, or provided by you during the research will be disclosed to others without your written permission, except: if necessary to protect your rights or welfare, or if required by law.

When the results of the research are published or discussed in conferences, no information will be included that would reveal your identity. If photographs, videos, or audio-tape recordings of you will be used for educational purposes, your identity will be protected or disguised. You will have the right to review and edit the video tapes. I will be the only person having access to them in order to analyze the design process. During this period I will have the video tapes locked in a cabinet in my house. After finishing with the analysis (about 2 months ) I will destroy them.

As the focus of the research is the design process, the video tapes will include only the act of designing – the participants hands and his/her drawings on paper. The face of the participant will not be videotaped.

- **WITHDRAWAL OF PARTICIPATION BY THE INVESTIGATOR**

The investigator may withdraw you from participating in this research if circumstances arise which warrant doing so.

If you must drop out because the investigator asks you to or because you have decided on your own to withdraw, you will be paid 10\$.

- **EMERGENCY CARE AND COMPENSATION FOR INJURY**

If you feel you have suffered an injury, which may include emotional trauma, as a result of participating in this study, please contact the person in charge of the study as soon as possible.

In the event you suffer such an injury, M.I.T. may provide itself, or arrange for the provision of, emergency transport or medical treatment, including emergency treatment and follow-up care, as needed, or reimbursement for such medical services. M.I.T. does not provide any other form of compensation for injury. In any case, neither the offer to provide medical assistance, nor the actual provision of medical services shall be considered an admission of fault or acceptance of liability. Questions regarding this policy may be directed to MIT's Insurance Office, (617) 253-2823. Your insurance carrier may be billed for the cost of emergency transport or medical treatment, if such services are determined not to be directly related to your participation in this study.

- **IDENTIFICATION OF INVESTIGATORS**

In the event of a research related injury or if you experience an adverse reaction, please immediately contact one of the investigators listed below. If you have any questions about the research, please feel free to contact  
Principal Investigator: George Stiny, (617) 253-0348, 77 Massachusetts Av. MA 02139, Cambridge.  
Associated Investigator: Magdalini Eleni Pantazi, (857) 753-9751, 18 Bigelow street, MA 02139, Cambridge.

- **RIGHTS OF RESEARCH SUBJECTS**

You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you feel you have been treated unfairly, or you have questions regarding your rights as a research

subject, you may contact the Chairman of the Committee on the Use of Humans as Experimental Subjects, M.I.T., Room E25-143B, 77 Massachusetts Ave, Cambridge, MA 02139, phone 1-617-253 6787.

**SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE**

I have read (or someone has read to me) the information provided above. I have been given an opportunity to ask questions and all of my questions have been answered to my satisfaction. I have been given a copy of this form.

**BY SIGNING THIS FORM, I WILLINGLY AGREE TO PARTICIPATE IN THE RESEARCH IT DESCRIBES.**

\_\_\_\_\_  
Name of Subject

\_\_\_\_\_  
Name of Legal Representative (if applicable)

\_\_\_\_\_  
Signature of Subject or Legal Representative

\_\_\_\_\_  
Date

**SIGNATURE OF INVESTIGATOR**

I have explained the research to the subject or his/her legal representative, and answered all of his/her questions. I believe that he/she understands the information described in this document and freely consents to participate.

\_\_\_\_\_  
Name of Investigator

\_\_\_\_\_  
Signature of Investigator  
same as subject's)

\_\_\_\_\_  
Date (must be the

**SIGNATURE OF WITNESS (If required by COUHES)**

My signature as witness certified that the subject or his/her legal representative signed this consent form in my presence as his/her voluntary act and deed.

\_\_\_\_\_  
Name of Witness



## **Appendix B. Questionnaire**

### **Designing with Rules**

**Name of Participant:**

#### **1\_ Formulation of the design idea and organization of design actions**

1\_ Did you have an idea at the beginning?

2\_ How did you proceed with your idea?

Describe the steps that you followed in order to achieve the first solution.

3\_ Did you repeat an action?

4\_ Did you develop an action regularly?

5\_ Did you reuse previous ideas or elements?

#### **2\_ Creation of the actual design**

Whenever there was an alteration in the design solution I would ask the architect to describe to me what led him/her to change the previous solution.

1\_ Why did you alter the solution?

2\_ Did you see something in the design?

#### **3\_ Comparison of the two design problems**

1\_ Do you have a specific strategy (pattern of actions) that you follow while designing?

2\_ How do you feel about constraints in design?

Do they help you?

Do you prefer problems that are less constrained?

3\_ Compare the two problems in terms of constraints.

Did the existence of constraints facilitate/hinder your exploration?

How?

4\_ Did the first exercise affect how you approached the second?

#### **4\_ Representational medium**

1\_ Which is the representational medium that you normally use?

2\_How did the representational medium affect your actions?

Did it limit the exploration of your ideas?

Did it enhance the exploration of your ideas?

## **Appendix C. Protocol Analysis**

### **#Architect A#**

#### **Design problem 01**

##### ***Formulation of the problem and organization of design actions***

The architect's reaction to the design problem was program oriented. She treated the design problem as a technical exercise, where she had to fit all the requirements in a specific amount of space. The square footage of the house became the most important design parameter for the architect. In her first sketch she created an 8x8 grid. She intended to block everything into the grid so as to understand space's square footage. However, she did not use the grid as a design tool, but rather as a measurement tool; a graphic paper that provides square footage guidelines. In the same sketch she grouped the programmatic requirements and decided to create a two story building.

A bubble diagram illustrating the first organization of the house functions appeared in the architect's second sketch. She created a general footprint schema for each floor, where she placed the groups of spaces. Furthermore, she examined the relationships with the adjacent buildings and decided not to exceed the neighboring boundaries.

##### ***Actual Design***

In the next three sketches the architect proceeded by dimensioning the previous bubble diagrams. Having calculated the approximate sizes of each room, she moved to the plan. There following the grid square footage guidelines, the architect examined possible room arrangements. Her final solution describes an open plan on the first floor with the following succession of spaces – living room, dining room, kitchen and entry space with bathroom. Circulation was happening through space. In the second floor the architect located the circulation corridor on the East side of the house and placed the room next to it. The four rooms of the second floor were placed in sequential order – master bedroom, room, room and bathroom.

The final two sketches composed a refinement of the finalized version decided in the previous series of sketches.

##### ***Rules in the Design Process***

The basic rule that the architect followed was that of arranging the programmatic requirements into the site. Her consideration of the site characteristics was limited to the adjacent buildings and more specific to their boundaries that could be used so as to define a general footprint for the house. Her process was based on program oriented constraints.

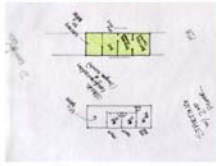
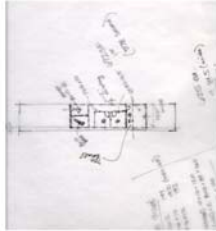
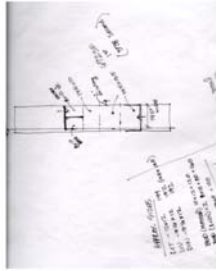


# Architect A\_ Design Problem\_01

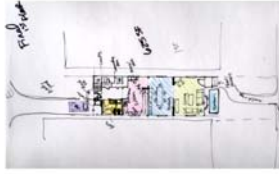
## Organization



## Design



## Solution



## **Design problem\_02**

### ***Formulation of the problem and organization of design actions***

The architect started by first considering a design parameter based on her personal desire for a two space house separated by a courtyard. This idea was attached to the nice climate of the area and the architect's wish to take advantage of the good weather of San Diego. She created a three story house.

In her first sketch, she designed the first floor, where she "split" the house in two parts with an open space in between. The architect then put a new tracing paper on the top of the first floor plan and continued with the next floor. There she did not keep on with the idea of the open space between two volumes, but she designed a compact volume. "I always assumed that there would be a roof," she said. Additionally, while she was following the general footprint of the floor below she decided to reduce the length of the second floor. She proceeded in the same way with the third floor. The gradual reduction of the house's space happened so as "to give a little bit of interest to the solution," as the architect said. This reduction did not follow a specific norm, but "each floor was big enough to get the circulation in," as she explained.

The architect then moved to the general site plan and examined the access to the house. That helped her to locate the house in the site.

A diagrammatic section followed, where the architect examined the circulation and the function of the spaces.

### ***Actual Design***

After having completed the diagrammatic sketches the architect proceeded in more detailed designs. She started considering the programmatic requirements of the design problem. She returned to the first sketch of the first floor plan. There she made an alteration: while initially the two volumes were totally separated, she decided to connect them with a circulation corridor, for efficiency reasons. On the first floor she located the kitchen in the South part and in the North the dining and the living room. The second floor consisted of two bedrooms and a bathroom and the third floor of the master bedroom and a bathroom.

Two last elevation sketches served as a proportional study of the house's openings and relation between the three floors.

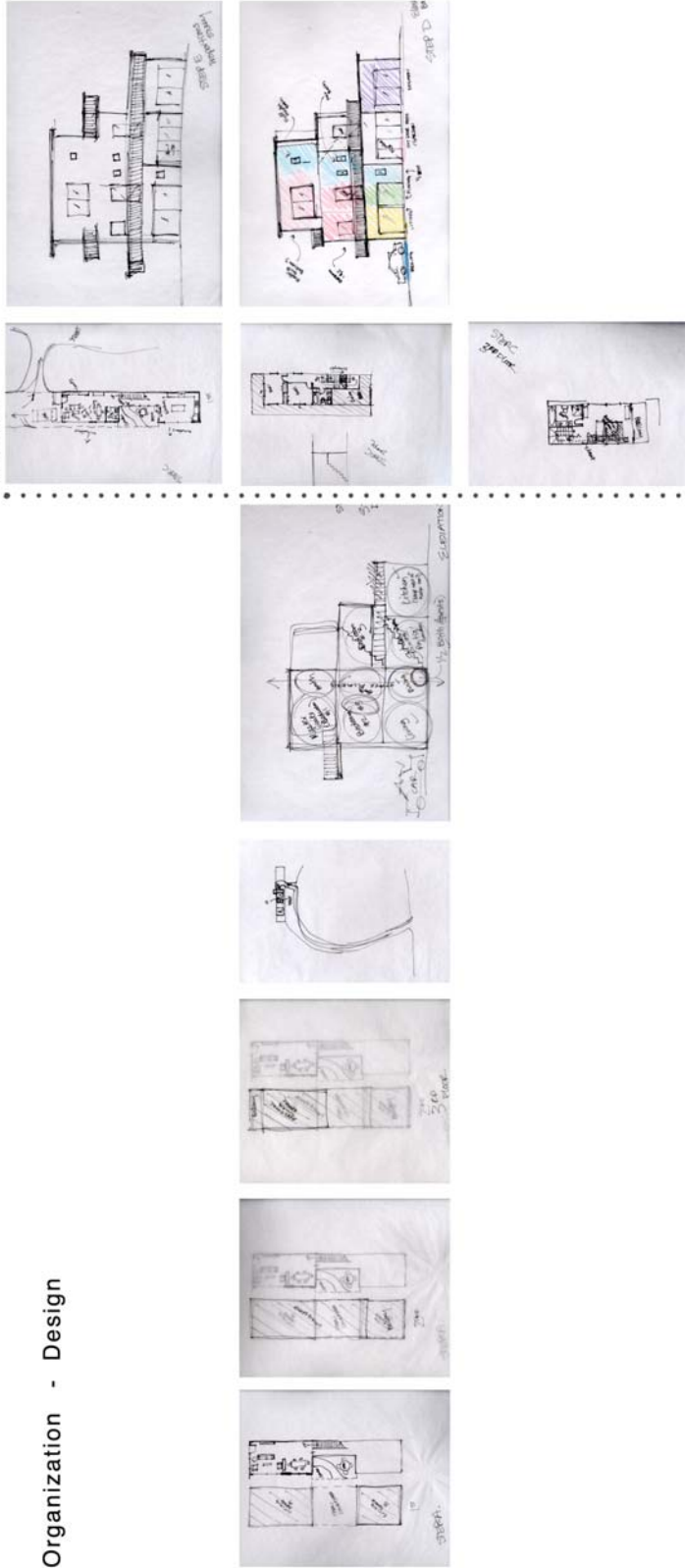
### ***Rules in the Design Process***

In contrast to the previous solution, the architect selected as guideline for the second design problem an idea related to a specific spatial arrangement. Fitting the programmatic requirements into the site was again an important issue for her, but the previous design exercise provided her with a basis upon which she could think; she had solved the problem of space organization and she was now free to explore other ideas. In this case, the process that the architect followed was based on personal oriented constraints.

Architect A\_Design Problem\_02

Organization - Design

Solution



## **#Architect C#**

### **Design problem\_01**

#### ***Formulation of the problem and organization of design actions***

The architect started by identifying the program and estimate the average square footage of each room. He said "I acted conservatively in this approach, in terms of space." He decided on the minimum size of each room and then proceeded in a diagrammatic sketch plan, where he started considering the house's footprint. At this point the architect introduced two design parameters to help him develop the solution: circulation and access to the house.

In the next three plan sketches the architect examined further the house circulation. In a separate sketch he started considering natural sunlight and more specifically the parts of the site that allow for maximum sunlight. In the last sketch of this phase the architect made a schematic plan of the second floor, where he examined the solution of a sequential arrangement of rooms around a corridor.

His response to the design problem's constraints was to start "with spaces and let them push around the rest of the program."

#### ***Actual Design***

The architect then proceeded with the second floor. He placed a corridor on the east side and aligned the rooms to it. He soon abandoned this solution because the lighting condition were not satisfying him. At this point the architect started considering the east side wall as a very important design element. His next decision was to locate the rooms in relation to it.

He actualized his decision on the next solution. He placed the corridor on the west side and aligned the rooms with the east wall. In this solution the architect used two types of circulation; one for horizontal and one for vertical movement. The horizontal movement took the form of a corridor running throughout the house, while the vertical movement was described by the stairs located at the south west corner of the house.

The architect was satisfied with this solution and he proceeded with the solution of the first floor. He selected a free plan for this floor and placed the circulation spaces at the same locations.

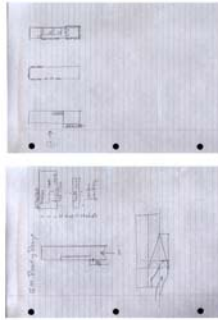
In the last two plan sketches, the architect proceeded by dimensioning the previous solution so as to meet the exact programmatic requirements.

#### ***Rules in the Design Process***

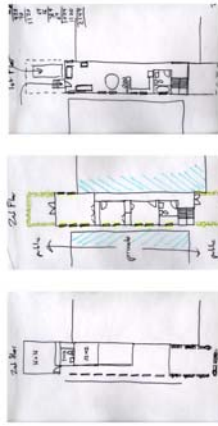
The basic concern of the architect was to arrange the programmatic requirements into the site. By taking into consideration certain site parameters, for example east side wall and the solar conditions, he proceeded in the creation of a general footprint where he examined different room arrangements. His design process was program oriented.

Architect C\_ Design Problem\_01

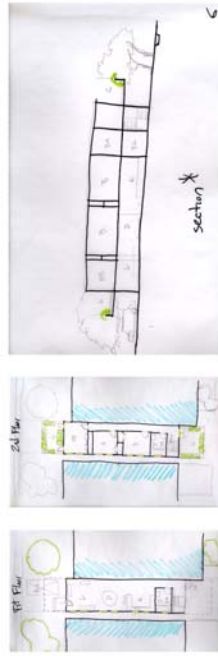
Organization



Design



Solution



## **Design Problem\_02**

### ***Formulation of the problem and organization of design actions***

The architect started by creating a schematic first floor plan. His first concern was to “gather the program together,” as he explained. In this first sketch he drew a rectangular floor plan sketch, and chose to proceed with a free plan type.

He then moved to the general site plan and started tracing the lines of the neighboring buildings, green spaces, and access to the site. At this point he started creating the idea of a big garden due to the good climate of the area. He wanted to create a house that would be as sufficient as possible. At the same time he wanted the house to be as private as possible. So he thought of space in a succession from public to private, with the house to serve as a block between the public and semi public space on the south of the site to the more private locate on the north. The last parameter that the architect was considering at this point referred to the views in relation to the sunlight, and more specifically how much sunlight he could get from each side of the house.

### ***Actual design***

The completion of the organization phase was followed by the designing phase, where the architect further developed his ideas. He drew the same rectangular free plan, where he rearranged the uses. At the opposite side the architect located the stairs for circulation purposes. He placed the kitchen on the south west side and dedicated the rest space for the living and the dining rooms. The architect put window in the three sides of the house. The garden constituted an important element of his design solution; it developed freely around the house and exceeded the site’s boundaries. Additionally, the garden did not stop at the house boundaries, but continued on the top of the house in the form of a roof garden. Small stairs were located next to the house to allow the access to the roof.

Being satisfied with the first floor solution, the architect moved to the second floor and started examining possible room arrangements.

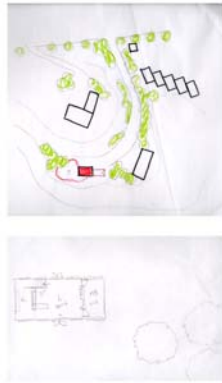
In the following three sketches he examined possible alterations of the second floor plan. The final configuration describes a sequential arrangement of rooms around a corridor placed at the opposite site of the stairs.

### ***Rules in the Design Process***

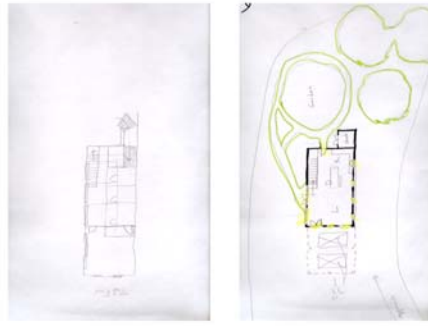
Working in the same lines with the previous design problem, the architect proceeded in the design process by trying to arrange the programmatic requirements into the site. His basic concern was to gather the program together, and so he proceeded by creating the minimum possible footprint that could accommodate all the functions. His design process was program oriented.

Architect C\_ Design Problem\_02

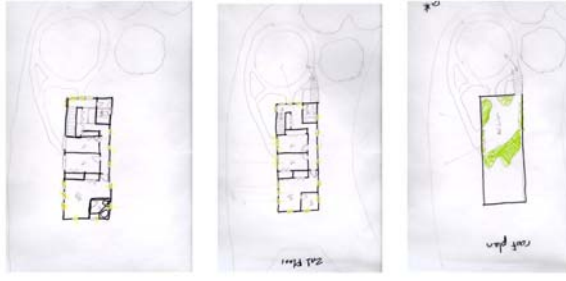
Organization



Design



Solution



## **# Architect E#**

### **Design Problem\_01**

#### ***Formulation of the problem and organization of design actions***

The architect started by drawing over the site plan in order to find what he called “the norms of the site.” He formulated the site’s information by tracing property lines, moving lines as well as defining desirable lighting conditions and green spaces. Following the lines of the site, the architect, (no need for the comma) first located the house’s footprint in alignment with the neighboring buildings. He then placed the accesses in the two open sides of the site. This moment was crucial, because it was the moment a precedent emerged: that of the typology of the shotgun building. “I felt that the site was topologically a shotgun” he observed and continued: “in this typology a building becomes the passage.” He used this observation to go on to the next step; he drew a line running through the site and indicating circulation. By placing this passage at the west side of the site, the architect started considering possible combinations of it with other parameters of the house, such as the lighting conditions. He decided to locate a skylight on the roof of the passage.

#### ***Actual Design***

Having decided on some basic ideas to work with the architect jumped to the computer, where he used the design software Sketch-up. In the digital environment he started giving three dimensional form to his concept. The idea of the passage was a dominant element that guided every action of the architect; a skylight was placed across it; the two-story building developed in alignment to it; and finally the back and front entries were placed at the beginning and at the end of the passage.

The architect proceeded only by exploring form. He did not consider the programmatic requirements of the design problem. He thought that this is something to reflect on, in a later phase. In his final solution, the architect basically described the basic mass arrangements of the house’s volumes.

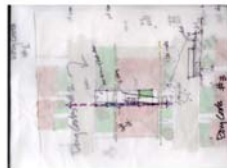
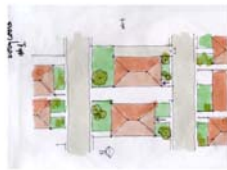
#### ***Rules in the Design Process***

In the above described process the architect proceeded as follows: he was looking for geometries on the site and whenever he came up with a geometric principal he was changing to sketch-up to define form. His process however is not based on site-derived constraints, but is rather described by personally oriented ones. The architect is looking to identify geometries on the site, but his solution is formed around a constraint that is imposed from somewhere else, in that case the shotgun typology.

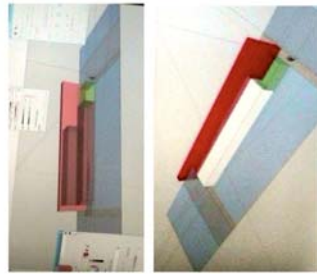
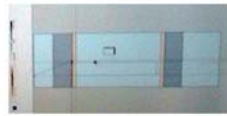


Architect E\_ Design Problem\_01

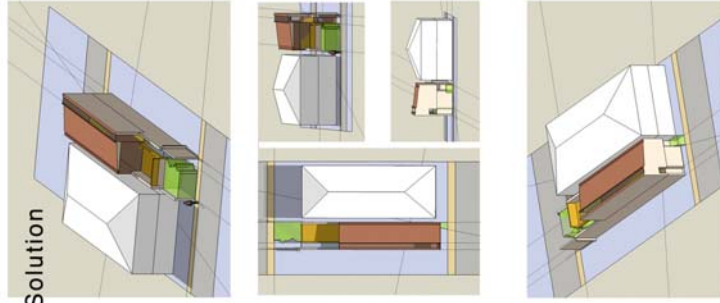
Organization



Design



Solution



## **Design Problem\_02**

### ***Formulation of the problem and organization of design actions***

In the second design problem, the architect again started by tracing the site's lines. After completing the first drawing, what he was looking at was a long narrow site in a beautiful landscape with great views and deep slopes. At this point, he proceeded by selecting some elements to work with : the roof and the ground. In a small section the architect defined their relationship and then proceeded again in sketch-up to further explore form. An interesting point, worth mentioning, is the form that the architect chose for the roof: an inclined surface. In the interview, the architect did not really explain where the idea came from. However later in the interview he mentioned Le Corbusier's Ronchamp, as an influence: the project with an interesting inclined roof.

### ***Actual Design***

The architect started by modeling his idea in Sketch-up and focused his working with the two elements that he was mostly concerned; the roof and its relationship to the ground. Another parameter that affected the roof's formation and which was introduced almost simultaneously by the architect, was the walled boundaries of the neighboring property.

As in the previous solution the architect selected an element and started working with it; the roof determined every design action. Therefore, when the architect saw together the roof and the ground, he realized the absence of a volume to accommodate the functions. And which is the form he gives to these functions? Two identical volumes. When, however, he inserted the volumes in the design, he realized he had to solve their relationship to the roof. So in the last step the two volumes were adjusted to the slope of the roof.

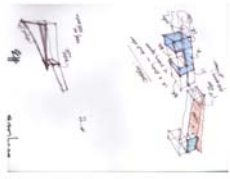
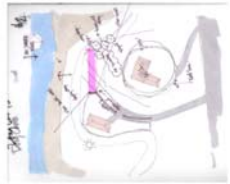
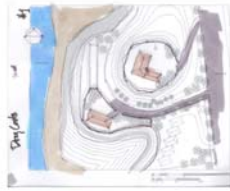
After having decided the basic volumetric characteristics of his solution, the architect proceeded to certain refinements; he decided on solid and void space, he located the entrance, he defined by the use of walls the boundaries of the site.

### ***Rules in the Design Process***

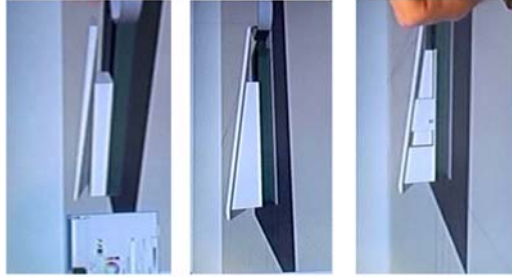
In the second problem the architect proceeded in a similar way. At the moment he defined the basic element, in this case the inclined roof, he jumped to Sketch Up to further explore the element's form as well as its relationships with other elements. The roof, which expressed a personal desire or constraint, constituted the driving force for both the design process and the design solution. The process was based on personal-derived constraints.

Architect E\_Design Problem\_02

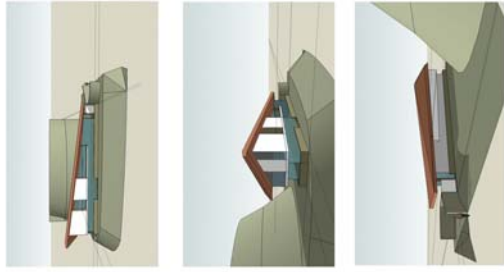
Organization



Design



Solution



## **#Architect F#**

### **Design problem 01**

#### ***Formulation of the problem and organization of design actions***

The architect's first concern was about the orientation of the building. In his first sketch he started tracing some lines of the general site plan. He was examining the adjacent buildings as well as the solar orientation trying to understand the qualities of the available site space. The architect's main consideration was about sunlight; he wanted the house to have as much sunlight as possible. After having formulated an idea of the characteristics of the site, the architect proceeded by writing down the programmatic requirements, trying to figure out possible spatial relationships. He estimated the average sizes of the rooms, so as to form a general idea on the project's size. The architect's last design on this sketch was a quick volumetric axonometric, where he examined the overall mass of a two story building.

In the next sketch the architect proceeded with some plan diagrams. Because his main concern was the sunlight, he decided to place the house at the North edge of the site where the absence of neighboring buildings was maximizing the sunlight. The house took the form of a square. Soon the architect realized that the created space was not enough to accommodate the programmatic requirements and so the house should expand in the site. This expansion created a linear house, which reminded to the architect the shotgun house typology. "Basically I knew it was a shotgun type of arrangement, where you need the rooms lined-up with each other," he said and that was the way he proceeded in his solution. In the next two designs on the same sketch the architect was considering the circulation, an important characteristic of the specific typology. He was examining different possible locations in relation to the best sunlight. The fact that there were no clear set backs led the architect to his final decision: he left a three feet circulation corridor in both sides, out of respect for the neighbors.

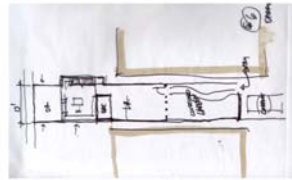
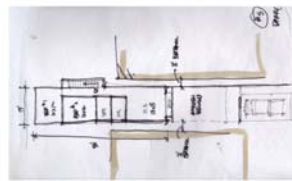
#### ***Actual design***

In the next two sketches the architect moved from the diagrammatic arrangement of spaces to a real one. He created an orthogonal house based on the shotgun typology. In the first sketch the architect located the interior spaces of the house in the following sequential order: living room, stairs, bathroom, kitchen, dining room. In the second sketch he moved to the second floor. There he spend some time considering alternative stairs' positions. As the architect did not like the stair location of the first floor he replaced it outside the main mass of the house; he pushed the stair back to the property line to allow more space to occur. "Clean circulation space – I do not have to worry about an internal stair breaking up the space," he explained.

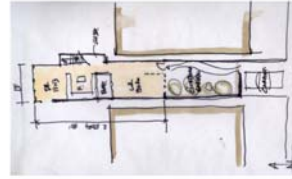
In the next four sketches the architect refined his solution. The last sketch presented few interior and exterior perspectives of the house.

Darryli\_ Design Problem\_01

Design



Solution



Through them, the architect was examining different features of his solution.

### ***Rules in the Design Process***

The architect proceeded in the design solution by first identifying the site's special conditions and constraints in order to find a basic guideline to develop his design solution. This process was combined with the architect's personal design principal of providing the house with maximum sunlight. The amalgamation of the above design parameters resulted in the shotgun typology.

At the beginning of the design process, which is the formation of the information contained in the design problem, the idea of maximum sunlight was a dominant characteristic of the design solution.

Interestingly though, as the architect proceeded in the solution, he did not hesitate to transform his initial idea as soon as a the first malfunction occurred. The architect's process coincide with Papazian's categorization of design as an "opportunistic" activity (Papazian, 1991). According to him, at any given time the designer focuses on specific parameters and evaluation criteria that could be triggered by a new element or situation. The rule that the architect followed in the first design solution was, therefore, opportunistic; he did not insist on his first ideas, but rather proceeded by altering them according to the new design situations.

## **Design Problem 02**

### ***Formulation of the problem and organization of design actions***

In the second design problem the architect started by generating a diagram. He traced few lines from the general site so as to identify site orientation and to examine natural benefits: views, solar orientation, group of trees, houses on the back, accesses. His response to the design problem was the creation of a tall building – a tower building – placed at the North edge of the site. This decision was partially influenced from the height restriction of the previous problem. The architect felt limited in the first design problem, where the building code constraint allowed the construction only of a two story building, and so he decided to create a taller house now that there was no height restriction. In his next move, the architect, started to consider the position of the house in relation to: the neighbors views, the group of trees and the views to the ocean.

As he continued to the next sketch the architect started to accommodate the house functions; stacking the program and computing the average square footage of each space. After having sketched few plan schemas the architect designed a section to examine circulation. At that point he realized that the access to the third floor was difficult; one had to climb too many stairs to reach it. Therefore, as he did in the first solution, he decided to alter his initial idea. He said, “Here I decided to reduce the concept of the tall- building” and proceeded by digging the house into the ground.

### ***Actual Design***

Starting with a section, the architect tried to accommodate the house programmatic requirements in a new sketch. As he had previously decided, he placed the house in the North edge of the site and located the house functions as follows: children bedrooms on the lower level, master bedroom on the ground level, living room and kitchen on the upper level. The house had a rectangular shape. To the other side of the site the architect located a rectangular open parking space. A bridge was used to connect the two parts. A continuation of the bridge idea was the division of the house in two parts: front and back. The front part was devoted to the rooms, while the back part to circulation.

In the next three sketches the architect proceeded with the organization of the floor-plans. At this point he started considering the entrances to the house. So far only one entrance existed, this from the parking area. For efficiency reasons the architect decided to place a second entrance straight from the street. This action affected the arrangement of the spaces in the house. The rectangular shape of the house on the ground level was divided in two parts. In the middle of them an opening was created as a continuation of the entrance point.

A last decision in this series of sketches was the transformation of the open parking space to a close one because “I had a desire for a lap pool and I was running out of space,” as he said. So he placed a lap pool on the top of the garage.

### ***Rules in the Design Process***

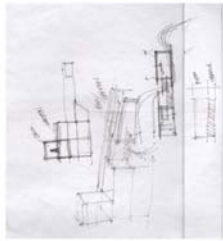
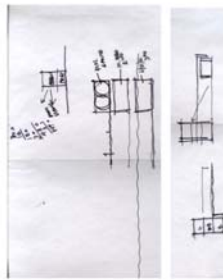
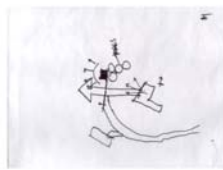
The architect proceeded in the design solution by first identifying the special conditions and constraints of the site in order to find a basic guideline to develop his design solution. This process was, again, joined with another parameter introduced from the personal vocabulary of the architect. This time it was the architect's personal desire for a tall building. The combination of the above design parameters created the guidelines for the design solution.

As in the previous solution the architect followed an opportunistic design method. When he realized that the idea of a tall building created some circulation problems, the architect did not hesitate; he reduced his concept and transformed the design solution into one that would solve the problems.

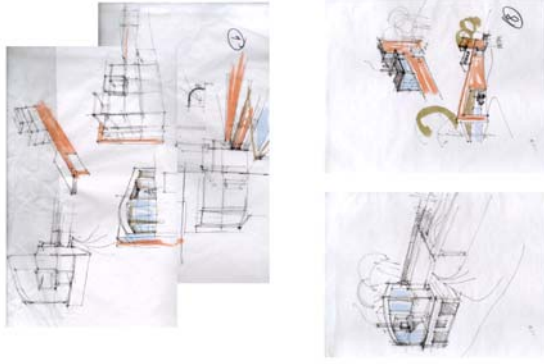
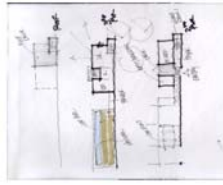
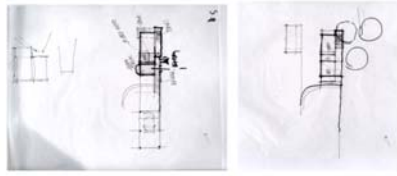


Architect F\_ Design Problem\_02

Organization • Design



• Solution



## **#Architect K#**

### **Design Problem\_01**

#### ***Formulation of the problem and organization of design actions***

The architect started by examining the scale of the site. He then pictured a story for the client so as to have a guideline to lead him to the organization of his actions towards the solution. He thought that the client is at his 50s and he does not really want to climb stairs everyday. The decision for a one story building was immediately formed. The second characteristic was related to the client's children. The architect thought that the organization of the space should allow the children to be close but separate at the same time. The last idea related to the client's characteristics was that "they are very neighborly and they respect the houses in either side." After having formed a picture for his client, the architect proceeded by investigating the surrounding properties, in an effort to get a sense of the envelope.

The architect then moved to a section sketch, where he examined the roofs of the adjacent buildings. There he realized that they are not something extravagant. At this point he decided to create a roof not higher from the roofs of the adjacent buildings.

He continued by thinking about elements related to the roof, such as the gutters. The location of them to the open space between the site and the next building, seemed a good idea to the architect and he proceeded with that. This spot between the two properties gained the architect's interest. He started considering it as an interesting point for increasing the natural light of the house. Furthermore, the combination of this lighting condition with the circulation corridor of the house, seemed a promising idea.

Another important characteristic, which the architect reflected on during that phase was the front door, the access to the house. Instead of having a direct front door as an entry to the house, he created a semi-private garden that would gradually lead to the entry point of the house.

#### ***Actual design***

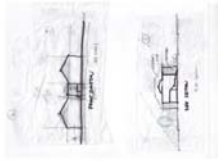
Then he moved to a plan and started putting all his ideas together. He made a series of sketches testing possible room arrangements. Early in that process he realized that he could not fit all the programmatic requirements on one floor, so he proceeded with a two story building. He decided to put only the kids' rooms in the second floor. But, soon he realized that even with this solution he will not be able to fit the program. And so, his last decision was to locate on the second floor the bedrooms and the living room. Through these sketches the architect also studied possible stair locations as well as light conditions in relation to them. The architect thought a lot about the sunlight issue. He was considering the garden location as well as the placement of the windows in terms of best sunlight conditions.

# Architect K\_Design Problem\_01

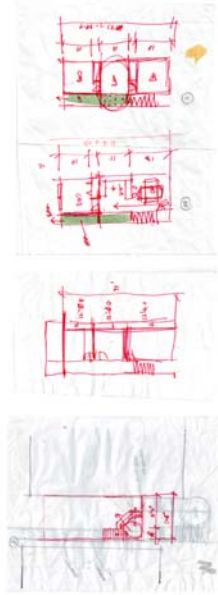
## Organization



## Design



## Solution



The last three sketches describe the architect's final solution. On the first floor, starting from the south, he located in sequential order: the semi-private garden, the dining room, the kitchen, the master bedroom and the parking space. At the west side of the house he located the stairs that led to the second floor. The stairs led to the central room of the second floor, the living room. Two bedrooms were located in either side of the living room. At this point the architect decided to locate a glass-roof window on the top of the living room, covering the area of the whole room.

### ***Rules in the Design Process***

The architect's process was not characterized by a dominant idea. On the contrary it seemed that the designer proceeded based on many minor ideas that were constantly combined to a different solution. Most of them relate to constraints imposed by the architect himself, in the form of personal principles and desires. Although the site constraints played a significant role in the architect's process, they were always affected and translated according to the architect's personal imposed constraints. The architect's design process was mostly personally oriented.

## **Design Problem\_02**

### ***Formulation of the problem and organization of design actions***

The architect started by tracing the lines of the site plan so as to “understand not only the topology, but also the paved areas, the green spaces, the views to the sea, the solar orientation, the neighboring buildings.” After the completion of the study of the site characteristics, the architect moved on to another sketch, where he drew a section to figure out the heights – slopes of the site and neighboring buildings elevations. At this point he introduced a parameter from the previous design problem; he thought again that the clients are very respectful people and do not want to block their neighbor’s views.” Therefore, the architect decided to place his house on the south side of the site so as to allow the neighbors views to the ocean.

### ***Actual Design***

In the next sketch the architect started exploring further his idea. He drew two axonometric sketches to examine the facades of the house in relation to the neighbors’ views. The house was a four-story building, described in elevation by an L shape. The two first floors were covering the whole area of the site, while the other two were expanding only in the one-third of the whole site area. The creation of this sketch helped the architect to form a decision; the back side of the house would be solid, while the front one open. The architect was planning to differentiate these two sides by using different materials.

The next sketches illustrate the designer’s attempts to organize the internal space. He started by creating a section of the stairs. Originally the architect was thinking the stairs as being something small, but as he proceeded with his solution the stairs became a very important element of the composition.

In a new tracing paper, the architect created some bubble diagrams of possible spatial room arrangements. He decided to locate the circulation on the back – east – side of the house. All the rooms were supposed to have views to the ocean.

The final house solution included four floors. From south to north on the first floor the architect located, the parking space, a storage area, and the master bedroom. On the second floor he located the kitchen, the dining room and the living room. Finally on the other two floors he located the children’s bedrooms, one in each floor. The final solution was characterized by the existence of many decks and balconies.

### ***Rules in the Design Process***

The architect followed the same process as in the previous solution, instead of having a dominant idea he proceeded with the combination of several minor ones. He said, “My initial ideas are good, but I never fall in love with them so quickly. I do it, give it up and then do something completely different. At the end I combine the two.” Although in this case, the architect started by examining the site conditions, he finally

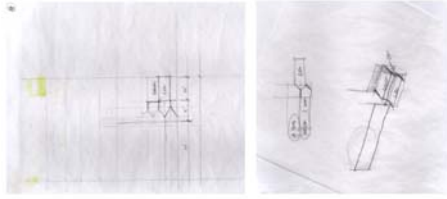
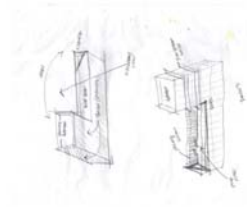
proceeded based on some personal constraints that composed his design process framework.

# Architect K\_Design Problem\_02

Organization

Design

Solution



## **#Architect M#**

### **Design Problem\_01**

#### ***Formulation of the problem and organization of design actions***

The architect started by tracing the lines of the site plan. He examined solar orientation, streets, neighboring buildings, set-backs. After the completion of this sketch the architect formed the first response to the design problem's constraints: a house with a courtyard in the middle.

#### ***Actual design***

Moving to the next sketch the designer located a garden in the middle of the site. The house developed on both sides of the garden. By this action the architect separated the public from the private space. The north part had two floors; in the first one the architect located the parking space and in the second the private rooms – bedrooms and bathrooms. At the south part the architect located in one floor the public functions of the building – living room. According to the architect this solution was recovered from his graduate studies, when he developed the idea of space division between the private and the public parts of the house.

The completion of this solution followed the development of a new one. The architect placed a tracing paper at the top of the previous solution and proceeded with a new solution. This time the garden was placed at the south side of the site, and the house expanded in the rest of the site. The architect developed a two story house, which had an orthogonal shape. The parking space remained at the same place at the back of the house. In that sketch the architect did not define the room arrangements.

The architects next move was to draw a section of the house. He designed his house together with the adjacent buildings. The creation of this section made him realize that the solar conditions for the first solution was of low quality and that the open space will constantly be in shadow. At this point the architect made a decision to proceed to the second solution – the one with the garden on the south.

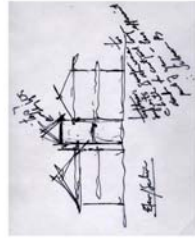
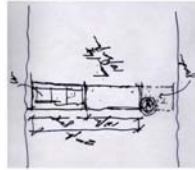
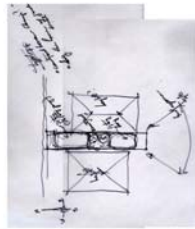
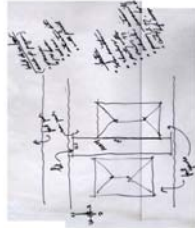
In a new tracing paper he started creating a diagrammatic sketch of the selected solution. He started with the first floor, where he located the public rooms of the house in the following order: living room, dining room, kitchen. A circulation corridor was placed at the east side of the site. The corridor was running throughout the house.

By placing a new tracing paper on the top of the first floor, the architect continued to the solution of the second. He aligned the rooms (two bedrooms, master bedroom and two bathrooms) of the second floor with the corridor. In the same sketch he drew a small section. An interesting thing happened there. The architect incorporated an idea developed on his first solution to the second floor of the second solution. He divided the second floor in two parts and placed an open space in the middle. By doing that the architect combined his two initial solutions to the design problem.

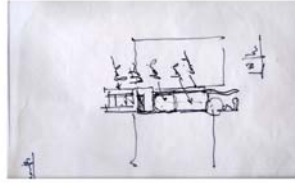
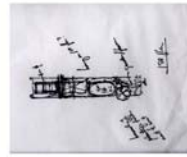
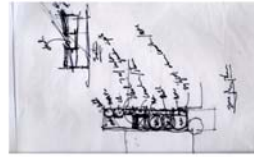


Architect M\_ Design Problem\_01

Organization



Design



Solution



The architect then proceeded with his final drawings where he refined the previous schematic solutions. In his final solution the circulation became a dominant element of space organization: all the rooms were aligned to it. Additionally, the corridor determined the horizontal movement in the house without including the stairs, which were located in a vertical relation to it.

***Rules in Design Process***

The architect developed a framework around the site constraints. He started by examining the special conditions of the site in terms of the solar orientation as well as the relation of his house to the adjacent buildings. He then proceeded by arranging the spaces according to the circulation, which again was defined by the peculiar shape of the site. His design process was mostly site oriented.



## **Design Problem\_02**

### ***Formulation of the problem and organization of design actions***

Similarly to his previous process, the architect started by tracing the lines of the site plan. He paid attention to the edges of the site because he thought that there were the best views of the site. He examined the access as well as the green spaces of it. At this point he decided to distinguish the back from the front side of his house. His last consideration in that sketch was about the roof shape. He decided to proceed with an inclined roof as a response to the site's slopes.

### ***Actual design***

From the schematic organization of the ideas and actions the architect proceeded to the actual design. There he started immediately with the plan of the first floor. After having designed the footprint the architect imposed a new constraint – a structural one. He placed columns into the site. He said "I think I wanted to get a little more direction, in terms of the plan, to probably create more parameters." He developed the solution pretty quickly by following the same lines with the design solution he created for the previous problem. Again a circulation corridor for horizontal movement was placed at the east side of the house and was running throughout the house. The spaces were aligned to this corridor and developed in the following order: dining room, kitchen, stairs, living room. On the second floor the architect kept the same corridor and developed the rooms in relation to it and in a sequential order.

In the last sketches the architect studied possible house elevations and sections.

### ***Rules in the Design Process***

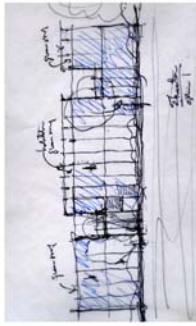
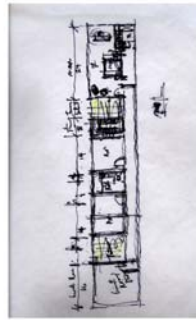
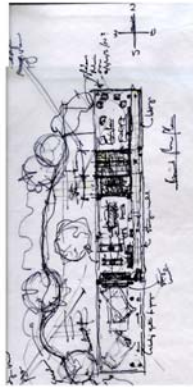
In the second problem the architect proceeded in a similar way with the first one; he developed a framework around the site constraints. He started by examining the special conditions of the site in terms of the solar orientation as well as in relation to the views of the house. In this process, however, the architect imposed an additional constraint outside the boundaries of the design problem, that of structure. He said, "I need rules, or I create rules in order to feel comfortable, because it short of forms the steps to the next steps, otherwise I feel like you make decisions without any guidelines. It feels more arbitrary." In the rest of the process, the architect continued by arranging the spaces according to the circulation, which again was an important element defined by the peculiar shape of the site. His design process, again, was mostly site oriented.

# Architect M\_ Design Problem\_02

## Organization



## Design - Solution



## **#Architect O#**

### **Design problem\_01**

#### ***Formulation of the problem and organization of design actions***

In the first design problem, the architect, after having read the program and briefly overviewed the shape of the site, she picked up and started working with the element of the corridor. In her first sketches, the architect, experimented with the relationship between spaces and corridor in three diagrams, trying to identify their possible relationships. In the first one, the rooms were aligned with the corridor; this solution was rejected as creating very private spaces. In the second one, the circulation was passing through the rooms; this solution was also rejected as being too public. The architect decided to proceed with a third solution, which was the combination of the two.

#### ***Actual Design***

Having decided on the relationship between circulation and rooms, the architect proceeded by applying it on the site, however without keeping the alignment. As she was working on the plan, she noticed the neighboring corridor. She decided to add one more on the other side of the site for ventilation reasons and moved to the section so as to test it. There she found her building squeezed between two taller ones prohibiting lighting and ventilation. So, she added a floor.

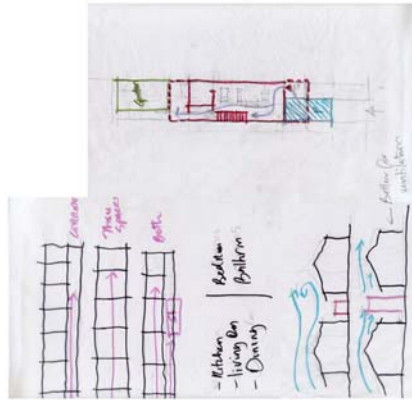
Moving to the plan of the second floor, she realized that the logic she followed on the first floor did not coincide with the prerequisites of privacy needed on the second floor. She placed another tracing paper on top of the first floor-plan drawing, and she introduced the first corridor solution that guaranteed privacy.

#### ***Rules in the Design Process***

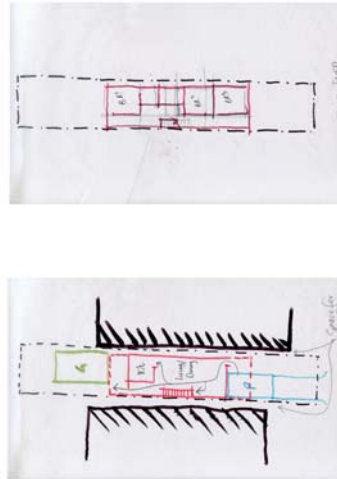
The architect started with a diagrammatic sketch to resolve the program. She then introduced the chosen spatial arrangement into the site and proceeded with the design solution. Her process was initiated and driven by (the arrangement of programmatic relationships) spatial relationships based on program.

Architect O\_ Design Problem\_01

Organization - Design



Solution



## **Design problem\_02**

### ***Formulation of the problem and organization of design actions***

In the second problem, the architect employed a slightly different problem so as to get familiarized with the information of the design problem. She started by tracing the lines of the site plan, trying to identify the site's characteristics. The views to the ocean got her attention and she decided to continue her work according to them. The architect, also laid down the programmatic requirements and realized that the program is similar to the program of the previous design problem.

### ***Actual Design***

The architect then proceeded by drawing the plan. There she thought of applying the solution of the previous problem, as the shape of the site was the same. However, when she designed the solution on the site she realized that the corridor constituted an obstacle to the view. From this stage to the next, she relocated the corridor to the other side. In this sketch another interesting transformation occurred. The architect first added an L-shape patio, for some "extra drama" as she explained. This extra drama however, proved to be a serendipitous moment. How? While designing the second floor, she traced the boundaries to the extra line of the patio underneath it by mistake. After a while, she realized the mistake and she redrew the floor based on the original boundaries. The rooms did not fit, so she decided to return to the previous solution and to integrate this mistake inside the proposal. The design process was informed by a "what I see is what I get" type of feedback relationship.

### ***Rules in the Design Process***

In the second design problem the architect started with a different approach, this of identifying the special characteristics of the site. However, the programmatic requirements constituted an important issue for her, an issue that she had to resolve. She proceeded (in that) by recovering the stored knowledge from the previous design problem. Her following step was to adjust the solution in the specific conditions of the site. As in the previous process the architect proceed based on program-derived constraints.

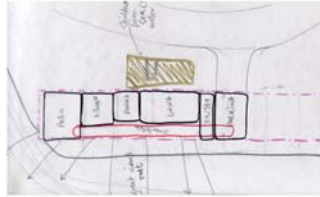


# Architect O\_ Design Problem\_02

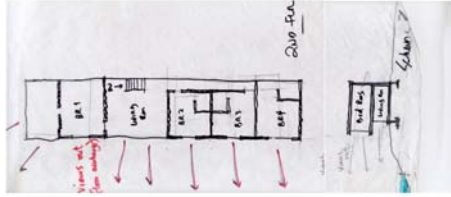
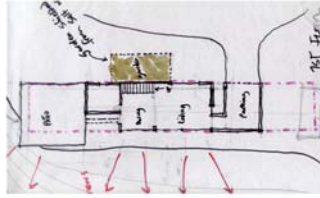
Organization



Design



Solution



## **#Architect S#**

### **Design problem 01**

#### ***Formulation of the problem and organization of design actions***

The architect started her exploration by investigating a possible footprint for the building. In order to do that she examined the boundaries and more specifically the characteristics of the shared walls – with thick black pen she designed the neighboring wall and with a dashed line the wall next to an open space. She then continued by laying down the program and drawing bubble diagrams to map up possible spatial relationships. During that process she made two plans – one responding to the first and one to the second floor.

#### ***Actual Design***

In her next step the architect moved to a bigger scale and proceeded with her idea of spatial organization. She examined both floors. She decided to put the circulation stair as a continuation of the entrance point. At these sketches she developed the idea of a skylight. The second floor opened to the first and a skylight was placed at the roof. In that way the sunlight could reach the center of the house. The size of the skylight was formed according to the second floor space organization. In her solution she incorporated a precedent image of Chicago buildings, described by the location of few stairs at the entry point of the house.

The architect then designed an axonometric to examine the openings of the house.

In the next sketches the architect explored further the room's arrangement. One of her main concerns and difficulties was the position of stairs. She could not match it with a satisfying second floor arrangement. This decision was also affected by another parameter imposed by the architect, that of placing the stairs near to the kitchen so as the opening/the skylight would provide some sunlight into the kitchen.

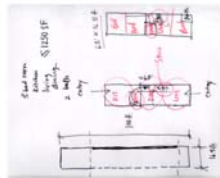
Reaching her final solution, the architect proceeded with an open plan for the first floor. She, finally, located the stairs somewhere in the middle of the house and next to the kitchen. In the south side she put the dining room and in the north side the living room. On the second floor apart from the circulation area of the stairs the architect formed another circulation area, this of a corridor and she put it to the opposite site. The bedrooms were located at the two edges of the house.

#### ***Rules in the Design Process***

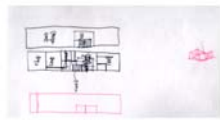
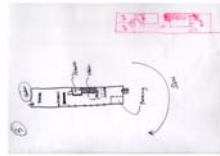
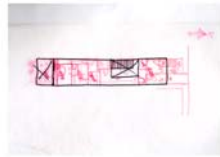
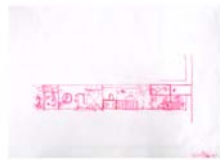
The architect developed a framework around programmatic constraints. She started by examining the programmatic characteristics of the design problem and tried to match them with a schematic footprint. Throughout her design process she tried to find a perfect match between the program and the footprint. Her design process was mostly program oriented.

Architect S\_Design Problem\_01

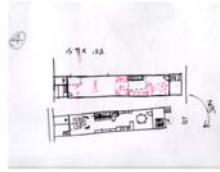
Organization



Design



Solution



## **Design problem\_02**

### ***Formulation of the problem and organization of design actions***

The architect's first move was to examine the topography of the site. She drew a simple section sketch where she examined the slopes of the site. Then she proceeded with a radical move; she created a simple rectangular house with a very strange roof, which resembles to roofs used in industrial buildings. This decision was explained later during the interview; the architect is currently doing her graduate studies on solar efficiency and she wanted to apply her knowledge to the design problem.

Having decided on the shape of the roof the architect conducted a plan diagram trying to define spatial arrangements. She decided to create a one floor building and to break it in two parts; one placed in the north and one in the south. She located dining room and kitchen at the north part and living room and sleeping space at the south part. The two parts were connected with an outdoor space. The characteristic of this space were the sliding doors, which could easily turn the outdoor to an indoor space. The main entrance of the house was placed there.

### ***Actual design***

In the next three sketches the architect developed further her ideas by drawing more detailed plans. In that process she decided to create a second floor at the south part of the house. There she located one bedroom on the ground floor and another one on the top of it. A small stair located next to the ground floor bedroom was leading to the second floor bedroom.

After having finalized the room arrangement she made her last design where she defined other areas such as the parking space and an entry from the beach, both located in the north.

Finally, the architect completed her design process by the creation of several elevation studies and one axonometric.

### ***Rules in Design Process***

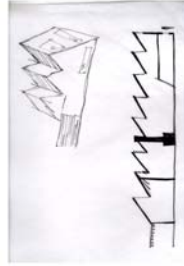
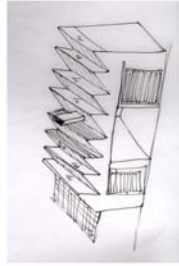
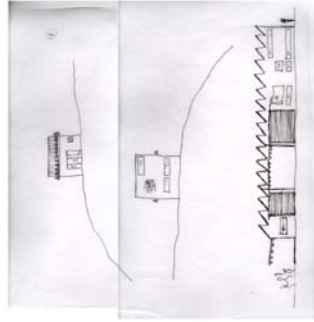
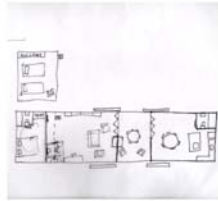
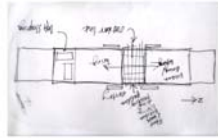
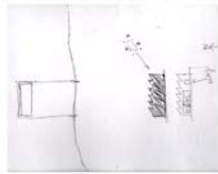
The architect proceeded in a different way for the second design problem. While in the first she was mostly concerned about the programmatic constraints, in the second case she imposed her own personal constraints so as to proceed with the solution. Of course she was taking into consideration the programmatic relationships, but she constructed the framework so as to proceed with her solution based on the idea of the "industrial" roof as well as the idea of house separation. The architect proceeded based on personal oriented constraints.

Architect S Design Problem\_02

Organization

Design

Solution



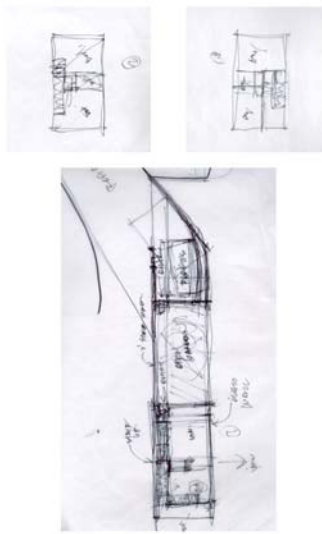
Architect B\_Design Problem\_01

Solution

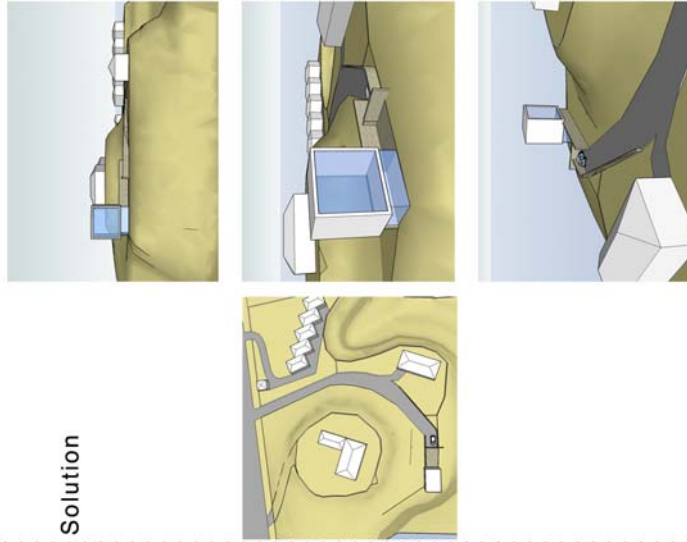


# Architect B\_ Design Problem\_02

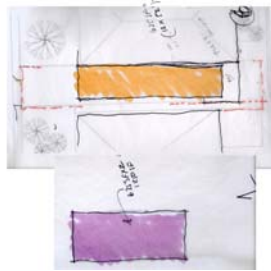
## Organization



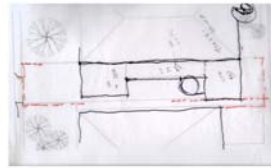
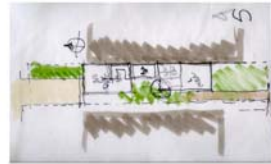
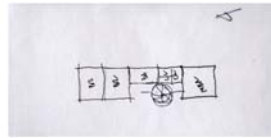
## Solution



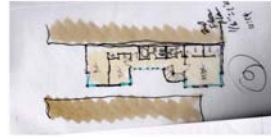
Organization



Design



Solution

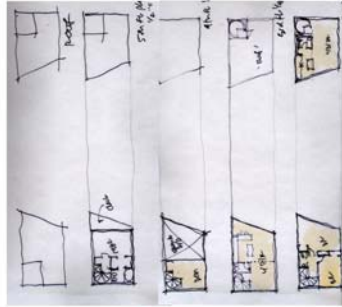
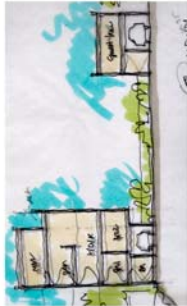
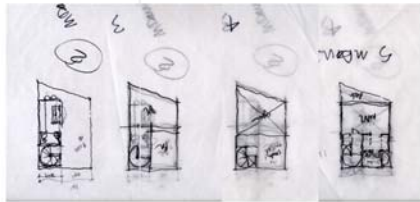
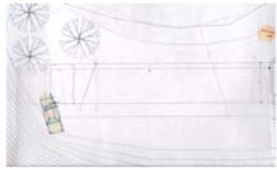




Organization



Design

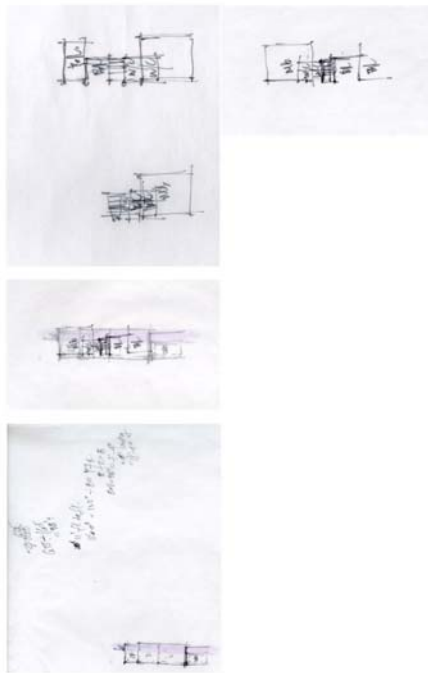


Solution



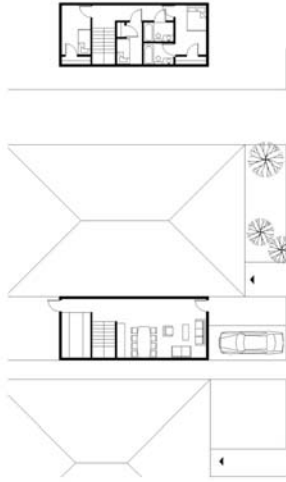
Derek\_ Design Problem\_01

Organization

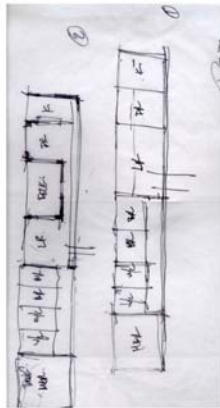


Design  
Autocad

• Solution

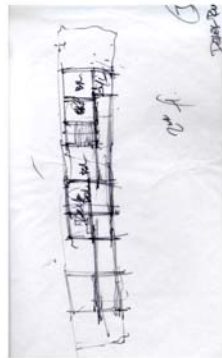
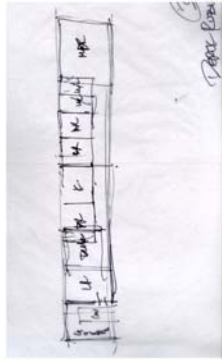


Organization

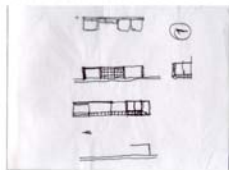


Design Autocad

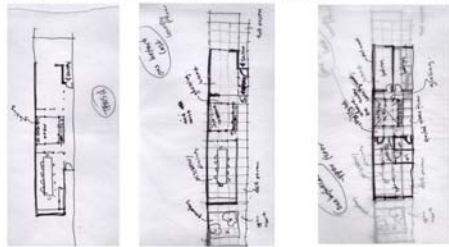
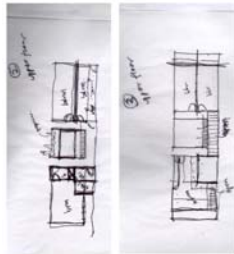
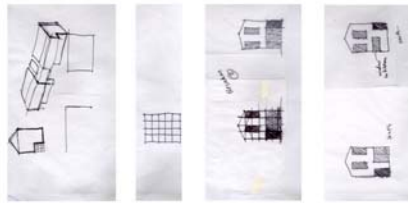
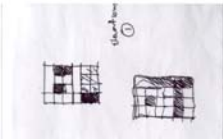
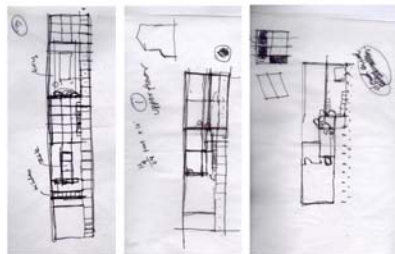
Solution



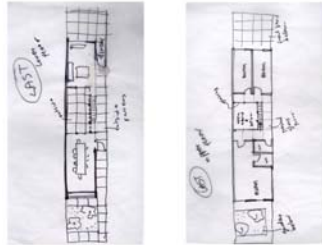
Organization

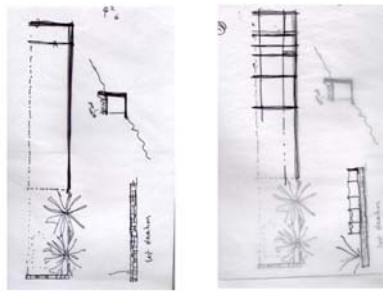


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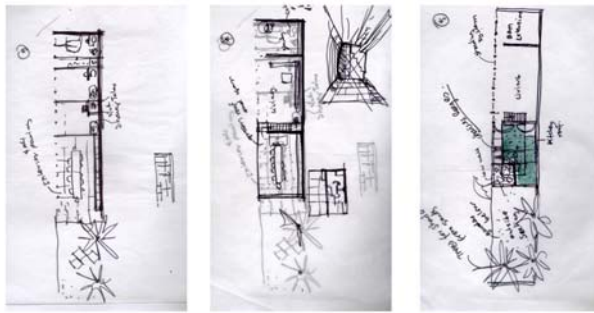


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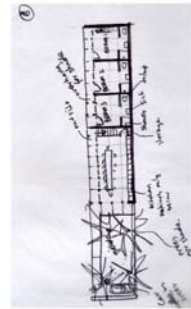
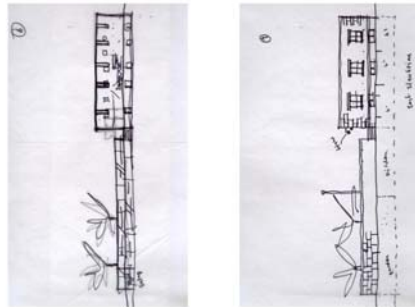




Design



Solution





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Figure 1: <http://www.thaistep.net/UserFiles/Image/eniac.jpg>, accessed on 05/23/08.

Figure 2: [http://www.mercurious.com/wordpress/wpcontent/uploads/2007/07/fig31\\_sketchpad.jpg](http://www.mercurious.com/wordpress/wpcontent/uploads/2007/07/fig31_sketchpad.jpg), accessed on 05/23/08.

Figure 3: Stiny, G (1985) Computing with Form and Meaning in Architecture, *Journal of Architectural Education* Vol 39, No1, p. 8.

Figure 4: Personal archive.

Figure 5: [http://en.wikipedia.org/wiki/The\\_Five\\_Obstructions](http://en.wikipedia.org/wiki/The_Five_Obstructions), accessed on 05/03/08.

Figure 6-41: Samples of the case study

Figure 42: Thomson, D (2000) *On Growth and Form*, University Press, Cambridge, UK, p.299.

Figure 43-51: Samples of the case study.

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[http://www.businessweek.com/innovate/content/feb2006/id20060223\\_523277.htm?chan=innovation\\_architecture\\_architecture+lead](http://www.businessweek.com/innovate/content/feb2006/id20060223_523277.htm?chan=innovation_architecture_architecture+lead), accessed on 04/27/08.